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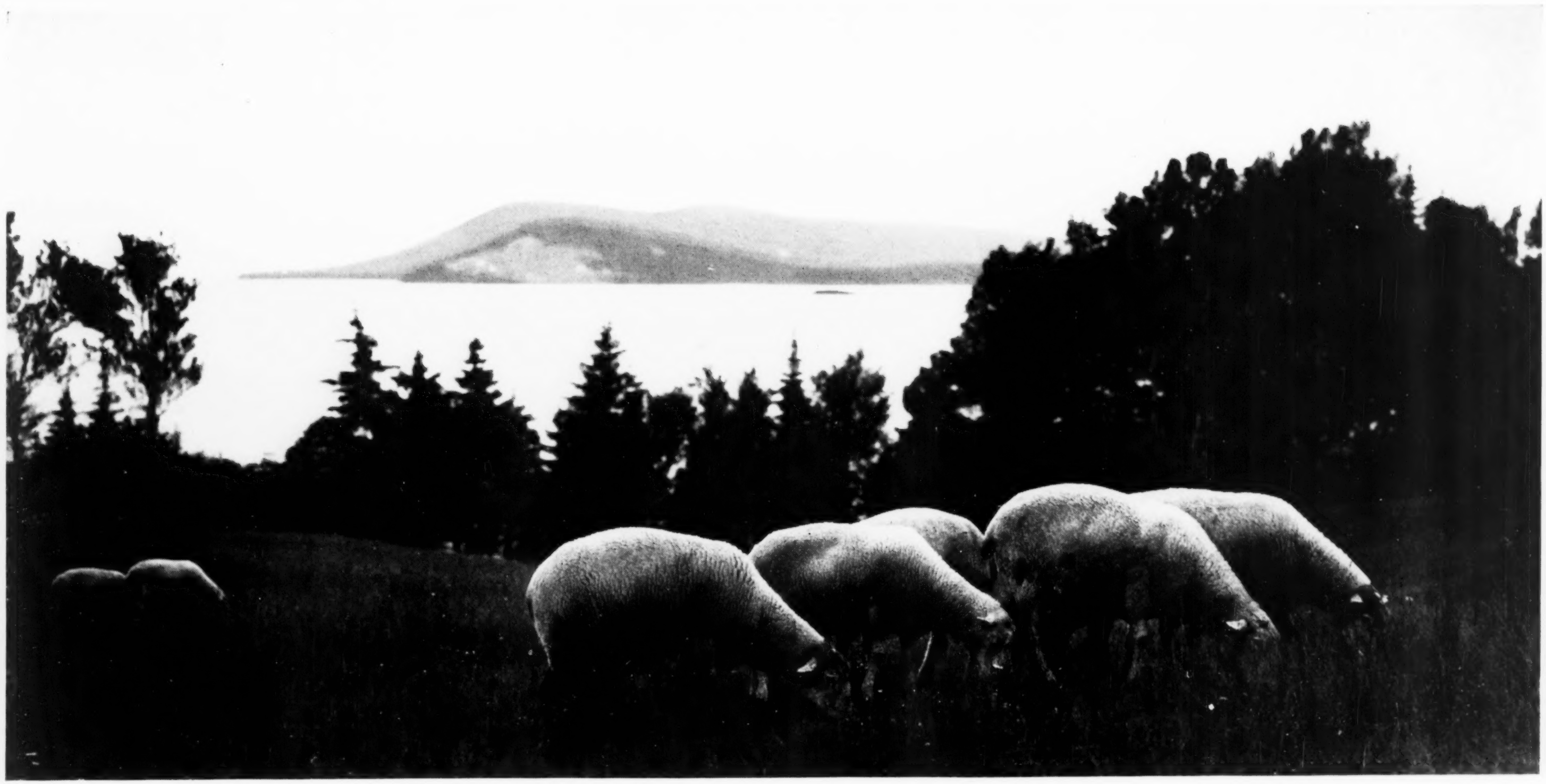


MULTI-NIPPLED SHEEP AT BEINN BHREAGH, NOVA SCOTIA

Most breeds of domesticated sheep possess two nipples each, but the ancestral form was undoubtedly the bearer of a number of nipples, and "sports" are frequently found in flocks, which show rudimentary nipples in addition to the two functional ones. Starting with some of these sports, Dr. Bell has gradually bred up a herd of sheep possessing supernumerary mammae, in an experiment covering a quarter of a century. At present his flock contains no ewe with less than six functional nipples, and some of them have had eight. In addition to this goal, Dr. Bell simultaneously bred to increase the twinning habit of the ewes, so that they might produce more lambs to enjoy these supernumerary nipples. This attempt has also met with promising success as a family of sheep has appeared in the flock in which the ewes have twins more frequently and at an earlier age than ordinary ewes, and yield a sufficient supply of milk for the support of two lambs. (Frontispiece.) Photograph by Arthur G. Eldrege, published by "Country Life in America."

SEX-DETERMINATION IN SHEEP

Effect of Special Feeding on Ratio of Males to Females and on Fecundity of Ewes—First Result Nullified by Addition of Data from Following Years—Method of Handling the Multi-Nippled Sheep at Beinn Bhreagh.

Compiled by the Editor from the Records of ALEXANDER GRAHAM BELL, *Washington, D. C.*

SINCE 1889, Alexander Graham Bell has been engaged in sheep-raising on his farm of Beinn Bhreagh, near Baddeck, Nova Scotia, in order to fix a breed possessing supernumerary mammae, and exceeding the ordinary breeds in fecundity. In the course of this experiment (which, it may be mentioned, has been a complete success) he has had an exceptionally good opportunity to test the theory that the sex of offspring is dependent, in part at least, on the nourishment of the mother, and also to test another hypothesis suggested in the course of his experience—namely, that the degree of nourishment had an effect in favoring the production of twins—one of the objects for which he was working.

On April 17, 1901, Dr. Bell read a paper on "Conditions affecting the Fertility of Sheep and the Sex of their Offspring," before the National Academy of Sciences at Washington, in which he explained the circumstances which favored his investigation of this problem of the influence of nutrition on the sex of offspring, as follows:

"For some years past my shepherd, Mr. John McKillop, has attempted to record periodically the weights of the sheep entrusted to his care, for the reason that weight has been found to give a valuable indication of the general physical condition and health. Sheep, when suffering from serious illness, nearly always lose in weight—indeed loss of weight is commonly the first indication that anything is wrong. This fact has been utilized to guard the Beinn Bhreagh flock from infectious disease. When a sheep is found to be losing unduly in weight, it is separated from the others and given special attention.

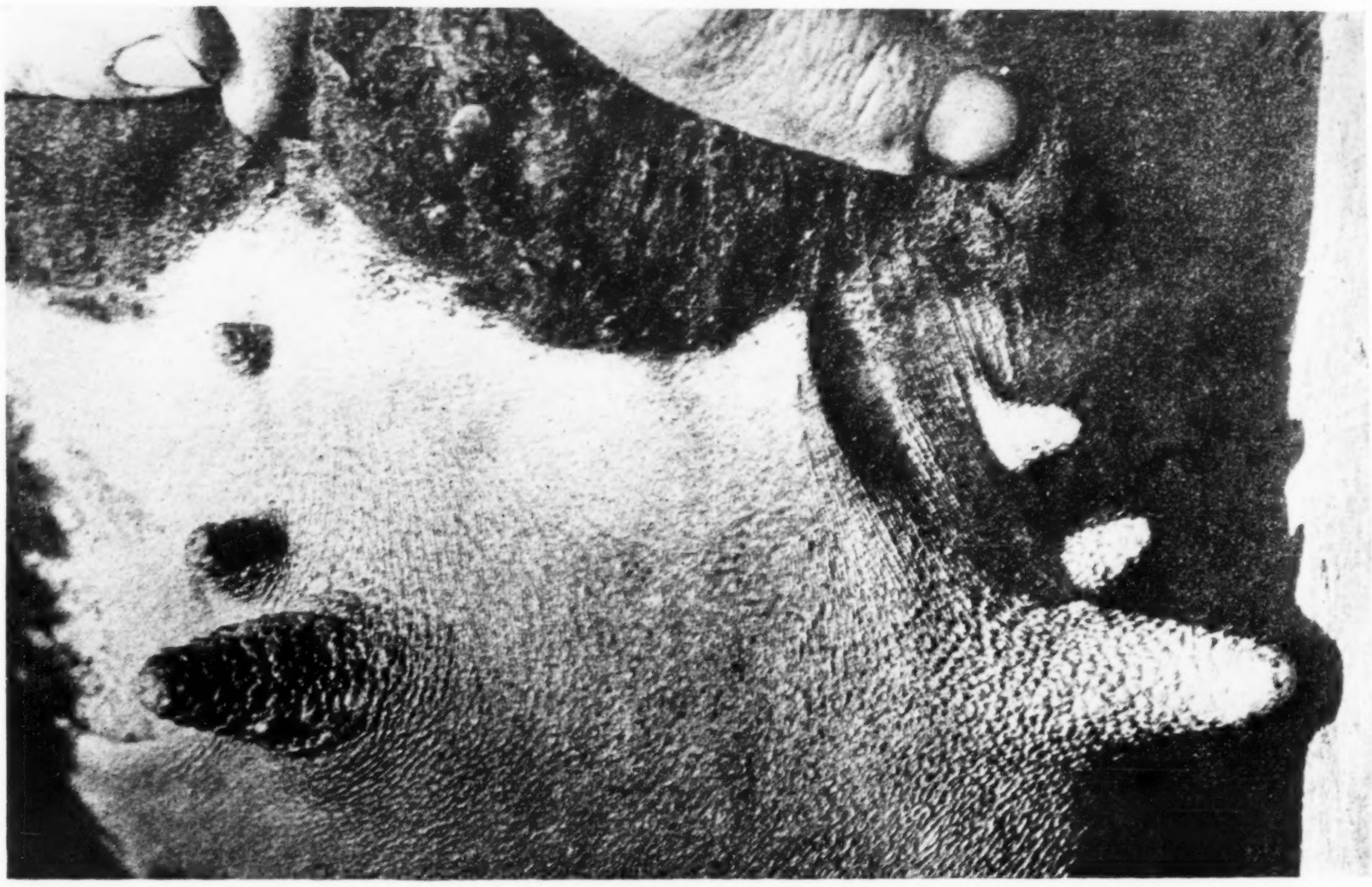
"In some cases these sheep have been found to be suffering from unsuspected diseases; in others unknown accidents had induced abscesses requiring surgical treatment. A decline in weight affecting a number of young lambs turned out to be due to the presence of tapeworm, and the lambs undoubtedly owed their lives to the timely discovery of the cause.

FLOCK WEIGHED FREQUENTLY.

"Experience having demonstrated that variations in weight are sometimes of great significance, the attempt was made to weigh the whole flock at least once a month.

"Unfortunately the summer and autumn records are imperfect, for it is not always easy or practicable to induce sheep to come and be weighed—especially when they are roaming about on a large pasture with plenty of cover. Still, a large enough number of records exist to enable us to ascertain the average weight of a Beinn Bhreagh ewe at the end of September, October, November, and December—thus covering the breeding season. Data were collected for this purpose in the summer of 1899 and the results show that the average weight increased rapidly up to the end of October. Beyond this point there was very little increase; and after the end of November there was an actual decline (which continued all winter under ordinary conditions of feeding).

"Thus, in Cape Breton Island, when mating occurs in October, the average ewe is improving rapidly in condition at the time of mating: When it occurs in November the weight is about the maximum, but increasing slowly: And when mating occurs in December the average



BELLY OF SIX-NIPPLED EWE.

In order to counteract the evil results of inbreeding, Dr. Bell has made it a habit to purchase all the multi-nippled sheep which he could find among his neighbors on Cape Breton Island. The photograph shows a ewe with six nipples, a natural "sport" which was found in a farmer's flock and added to the Beinn Bhreagh flock. (Figure 1.)

ewe is in failing condition, slowly losing weight from day to day."

As careful record was kept of the matings, and the births of lambs, this record was then compared with the weights of the ewes, at various times during the period of gestation. Dr. Bell's conclusion was that:

WHEN TWINS ARE BORN.

"Three conditions favorable to the productions of twins revealed themselves:—

1. *Maturity in the Ewes*—(Ewes four, five and six years old yielding a larger percentage of twins than younger or older ewes);
2. *Mating in October*—(With consequent lambing in March); and
3. *A rapid increase of weight at the time of mating with subsequent loss of weight.*

"The third condition seemed to be eminently susceptible of control; and in the autumn of 1899, the attempt was made to influence the weight by special feeding.

"Beginning in the latter part of September, 1899, each ewe was given a feed of oats twice a day in addition to the grass picked up on the pasture. After mating had been accomplished the extra feed was discontinued.

"It was expected that under this treatment the ewes generally would gain abnormally in weight up to the period of mating, after which the weight would gradually fall (on account of the discontinuance of the extra food) until the normal weight had been reached due to the natural condition of the pasture. The weight-curve characteristic of the twin-bearing ewes might thus perhaps be simulated; and the query arose:—Would the production of twins be increased?

"The whole flock was subjected to the experiment during the month of October, 1899, after which the extra feeding was discontinued with all. The experiment therefore was only complete

in the case of the ewes that were mated in October—the mothers of the 36 lambs born in March, 1900.

"The weight records show that the desired fluctuations of weight actually occurred, and occurred—not only with the twin-bearing ewes, but with the single-bearing as well.

"The fluctuations of weight seem to have been somewhat greater with the twin-bearing than the single-bearing ewes—which is consistent with former observations.

"Forty-five lambs were born in the spring of 1900; and of these, 16 or 36.6% were twins (eight pairs). This was a smaller percentage than in 1899, although above the average for the decade 1890-1899. Thirty-six of these lambs were born in March 1900—including all of the twins—16 in number or 44.4%: This percentage was less than the average for March lambs during the decade 1890-1899; but four of the single lambs were from two-year old mothers. If we deduct these we find that 32 lambs were born in March 1900 from ewes three years of age or older—16 single lambs and 16 twins (yielding the maximum percentage hitherto attained).

"On account of the small size of the flock, a very slight change in the absolute numbers would make a considerable change in the percentages."

The data, then, were not conclusive as to whether the extra feeding given the ewes in the fall of 1899 had caused them to produce a larger percentage of twins than ordinary. But, continues, Dr. Bell:

"While the effect upon productiveness was not well marked it would be premature to conclude that no effect at all had been produced by the special feeding; for no less than 72% of the March-born lambs were females—a circumstance quite unprecedented in the history of the flock.

"Of course the absolute numbers were small—only 36 March-born lambs in all (10 male and 26 female)—but the preponderance of females was too marked to be entirely accidental, more especially when we consider that the average of the flock for ten years showed males in excess.

"Both among twins and single lambs females predominated in March 1900. Five pairs of male and female twins were born in that month, and three pairs in which both twins were female:—Total eight pairs. No case occurred in which both twins were male. Thus—out of 16 twins, five were male and 11, or 68.75% were female. Out of 20 single lambs five were male, and 15 or 75% female.

"If climatic conditions were involved, or general causes of any kind affecting the whole Island of Cape Breton, it seemed reasonable to suppose that an unusual proportion of female lambs would be found in the Island generally in the spring of 1900.

"My shepherd, Mr. John McKillop, and Mr. Angus McInnis, of Beinn Bhreagh, undertook an investigation of this point; and, in May, 1900, they collected statistics from the neighboring farmers concerning the number of male and female lambs born that Spring. Thirty-two flocks were examined, containing 371 lambs,—202 of these were males and 169 females.

"In four flocks the males and females were equally divided. In 14 flocks males were in excess, and in 14 flocks females. The summation of the whole shows a majority of males (54.4%):—The large female percentage upon Beinn Bhreagh was evidently, therefore, a local matter.

"In flock No. 23, belonging to Mr. Farquhar Macrae, an unusual proportion of male births occurred. Out of 26 lambs born upon his place no less than 23 (or 88.5%) were males, and only three (or 11.5%) were females.

"This fact led to a special investigaiton of the treatment of his flock during the preceding year (1899). It was found that in the autumn of 1899 the ewes were roaming at large upon an upland pasture, unaccompanied by males, until the middle of November, when the ram was released and allowed to run with the flock. The sheep received no care until starvation drove them to the barn, in the middle of January, 1900, after which they were given a daily ration of dry hay. In this case, then, mating occurred late in November, or early in

December, 1899, at a time when the ewes were beginning to lose weight on account of failing pasture—after which they remained in reduced condition until their lambs were born. Under these circumstances 88.5% of the lambs were males; whereas in the Beinn Bhreagh flock, where the ewes had been specially fed, 72.2% were females (of the March-born lambs).

"These facts seem to indicate that perhaps, after all, the special feeding in the autumn of 1899, may have been responsible for the large proportion of females born in 1900.

DIFFERENCES IN WEIGHT.

"If the nutrition of the mother during the early period of gestation is an element in determining the sex of her offspring, we may reasonably hope to observe some characteristic differences of weight between the mothers of males and the mothers of females at this period. The records of the Beinn Bhreagh flock are sufficiently voluminous to enable us to examine this point.

"An inspection of the figures shows that the differences of weight are slight, but, on account of the considerable numbers involved it may well be that they are significant. At the beginning of October, before mating had been accomplished, the average weights of the two classes of ewes (male-bearing and female-bearing) were the same.

"The average male-bearing ewe increased in weight up to the end of October, after which there was a decline: The average female-bearing ewe, on the other hand, continued to gain in weight all through November so that by the end of that month the average female-bearing ewe outweighed the male-bearing—a superiority retained during the subsequent decline.

"Such being the results in the case of matings during the decade 1890-1899, we added the data for the lambs born in March 1900, from matings which occurred in October, 1899. In all these cases the mothers were specially fed, as described above, up to the time of mating.

"Here again we observe a reversal in the relative weights of the two classes of ewes. The male-bearing ewes, on the average, outweighed the others at the beginning of the period of gestation, but after mating lost weight so much more rapidly than the female-bearing ewes that the latter soon became the heavier.

MOTHERS OF TWINS HEAVIER.

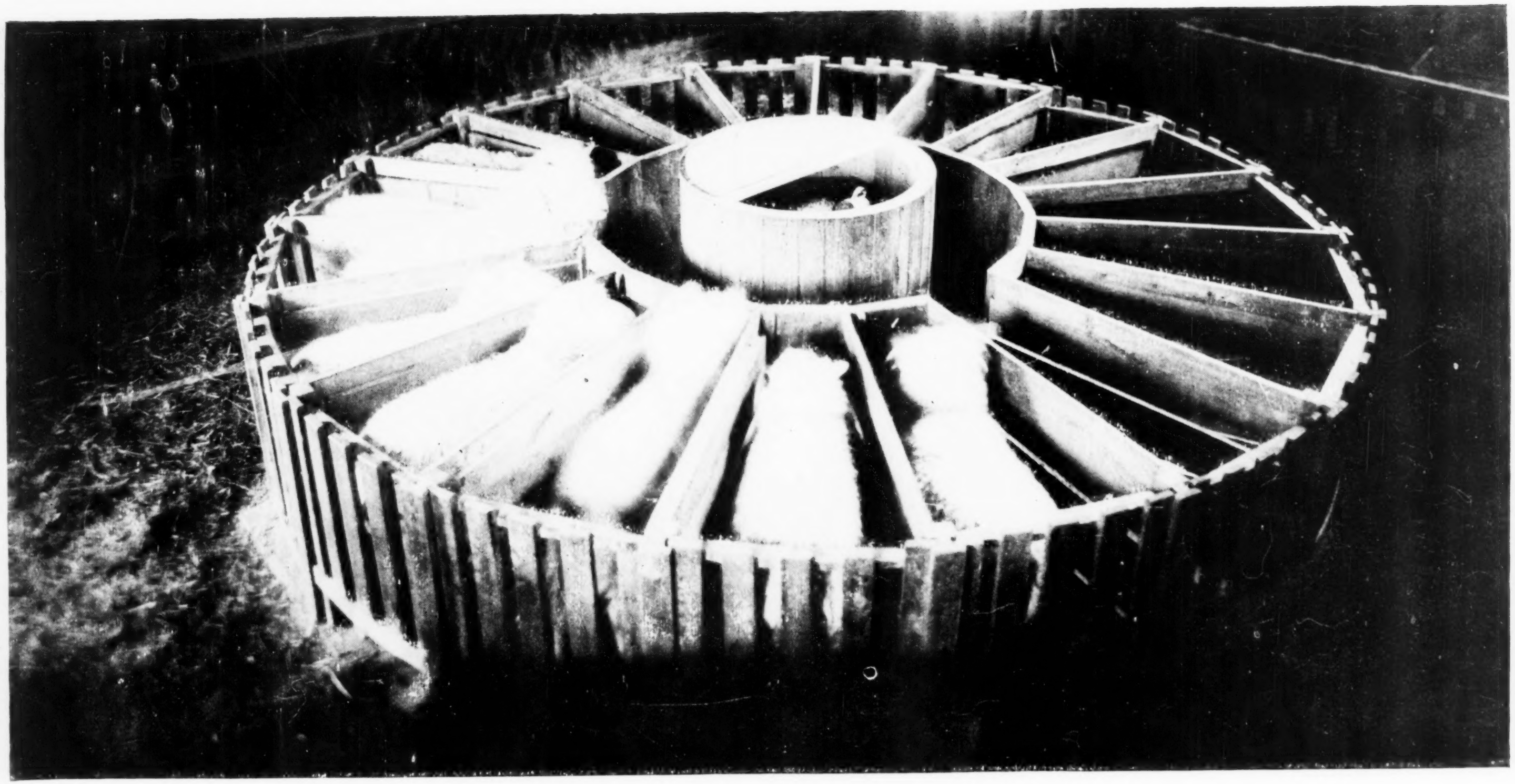
"In order to afford data for more detailed examination of changes of weight, these ewes were weighed once a week during the whole period of gestation. We found that the mothers of twins were above the average of the flock in weight; and the mothers of single lambs were below the average.

"Among the single-bearing ewes the mothers of males averaged less in weight than the mothers of females. It was noticed that the mothers of males were losing in weight at the time of mating, and immediately after mating, whereas the mothers of females substantially retained their weight for some time after mating.

"Among the twin-bearing ewes there were none who had male lambs exclusively. Those who had male as well as female lambs were losing in weight at the time of mating and immediately after; whereas those who had female lambs alone were increasing in weight at the time of mating, and, though the weight dropped afterwards, did not continue to drop but remained substantially on a level for several weeks. Those who had twins, male as well as female, were nearly 12 pounds heavier than those who had twin females alone, at the beginning of the period of gestation; but subsequently lost weight so rapidly that seven weeks after mating they had lost their superiority in this regard.

"All these ewes were given a special feed of oats twice a day up to the time of mating, after which the extra feed was discontinued, the ewes then deriving their sole nourishment from the pasture.

"The aggregate and average weekly weights, in the autumn and winter of 1899, of the 20 ewes who had single lambs in March, 1900, and of the eight ewes who had twin lambs, were also compiled, with similar results. Not only were the twin-bearing ewes very



FEEDING THE EXPERIMENTAL FLOCK OF SHEEP

In order that the gluttons might not have an advantage, and thus wreck an experiment based on the carefully ascertained weight of the sheep, each one was fed separately, so that he could get as much as he wanted. The sheep were weighed daily just before being fed, and from the fluctuations of weight it was thought that those ewes which bore female lambs were the heavier. The conclusions on which this belief was based were nullified by the addition of more data, however. It is not certain, either, whether any definite relation between changes of weight and the tendency to produce twins can be noted. (Fig. 2).

much heavier on the average than the single-bearing ewes, but their weight increased much more rapidly for some time after mating.

SIGNIFICANT DECLINE.

"We then calculated the aggregate and average weekly weights of the mothers of the 10 male lambs born in March, 1900, and of the mothers of the 26 female lambs born at the same time.

"The male-bearing ewes, on the average, weighed more than the female-bearing at the time of mating, but lost weight so much more rapidly after mating, that in a few weeks the female-bearing ewes were the heavier, a superiority afterwards retained throughout the whole period of gestation.

"The male-bearing ewes were losing in weight at the time of mating and immediately afterwards, in a much more marked degree than in the case of the female-bearing ewes.

"In the above calculations, the weights of the five ewes who had both male and female twins were included once among the mothers of male lambs, and once among the mothers of female lambs.

"A second computation was made, from which these ewes were excluded, so that it referred to ewes who had male lambs exclusively, or female lambs exclusively. It was found that the mothers of males averaged less in weight than the mothers of females; but the characteristic changes of weight at or about the time of mating are the same as noted before. The mothers of males were losing in weight at the time of mating; whereas the mothers of females retained their weight."

On the basis of these figures, Dr. Bell placed on record the following "Conclusion":

"It is to be regretted that the number of cases examined in this paper is too small to enable us to feel full confidence in the accuracy of the results, but the indications seem to point to the conclusion that variations of weight occurring at or about the time of mating may have great significance.

"They reflect changes in the condition of nutrition of the mother, at a critical period in the formation of the unborn young; and suggest the possibility of affecting the fertility of sheep, and controling the sex of their offspring, by suitable feeding for a short period of time before and after the time of mating."

INVESTIGATION RESUMED.

Such was the status of the investigation at the close of Dr. Bell's first ten years of work with this breed of sheep. He did not publish the paper abstracted above, however, but merely placed it on record among his own papers, making a note that "Some of the conclusions suggested were of so startling a character that it was thought better to await the collection of larger statistics before publishing the results."

In 1901 he returned to this subject, and on October 17 dictated a memorandum of the above results, continued by the following comment:

"These results have afforded some ground for the belief that there is a sensible difference in the weight changes of the mothers of male and female lambs about the latter part of October or the early part of November; and that loss of weight is associated with the production of male lambs; increase of weight at this time associated with the production of female lambs.

"I have always felt, however, that the absolute numbers involved were too small to give certainty to the averages and I still feel that we must wait for more numerous observations before announcing definite conclusions.

"It has occurred to me that by adding the lambs born 1900 and 1901 to those born during the decade 1890-1899, the absolute numbers involved would be increased, and the averages resulting therefore more certain."

The data made available in 1901 resulted from the birth of thirty-two lambs at Beinn Bhreagh, 14 male, and 18 female. The mothers of the 14 males weighed 1293 lbs. at the end of September, 1900; 1267 lbs. end of October; 1238 lbs. end of November; 1221 lbs. end of December; average weights 92.4 lbs. September; 90.7 lbs, October; 88.4 lbs. November; 87.2 lbs. December.

The mothers of the 18 female lambs weighed 1561 lbs. end of September, 1900; 1667 lbs. end of October; 1535 lbs. end of November; 1495 lbs. end of December. The average weights being: End of September 86.7 lbs.; October 92.6 lbs.; November 85.3 lbs; December 83.1 lbs.

Dr. Bell therefore prepared a table combining all the observations accessible from his records, as follows:

Weights of Mothers of Male Lambs

(Taken in Autumn preceding birth of lambs)

	September 30		*October 31*	
Date of Birth of Lambs	*No. of Cases.*	*Weights in lbs.*	*No. of Cases.*	*Weights in lbs.*
1890–1899	102	9029	108	10390
1900	10	1055	10	1105
1901	14	1293	14	1267
Total	126	11377	132	12762
Averages	.....	90.3 lbs.	.....	96.6 lbs.

	November 30		*December 31*	
Date of Birth of Lambs	*No. of Cases.*	*Weights in lbs.*	*No. of Cases.*	*Weights in lbs.*
1890–1899	120	11502	76	7227
1900	10	1023	10	957
1901	14	1238	14	1221
Total	144	13763	100	9405
Averages	.....	95.6 lbs.	.....	94.0 lbs.

Weights of Mothers of Female Lambs

	September 30		*October 31*	
Date of Birth of Lambs	*No. of Cases.*	*Weights in lbs.*	*No. of Cases.*	*Weights in lbs.*
1890–1899	81	7154	85	7948
1900	26	2680	26	2816
1901	18	1561	18	1667
Total	125	11395	129	12431
Averages	.....	91.2 lbs.	.....	96.4 lbs.

Weight of Mothers of Female Lambs (Continued).

Date of Birth of Lambs	*November 30*		*December 31*	
	No. of Cases.	*Weights in lbs.*	*No. of Cases.*	*Weights in lbs.*
1890–1899	99	9545	58	5553
1900	26	2727	26	2536
1901	18	1535	18	1495
Total	143	13807	102	9584
Averages		95.2 lbs.		94.0 lbs.

DIFFERENCE DISAPPEARS.

"The results," as he notes "are rather startling. It would be unnecessary to give a graphical diagram, for it is obvious from inspection of the tables that the average weights of the mothers of male and female lambs taken at the end of October, November and December, of the year preceding the birth of the lambs *were the same*. So that the two curves would be absolutely identical.

"What this means I do not yet know. The first impression made upon the mind is, that the former results were fallacious because based upon small numbers. In the above case the smallest number of cases used in determining an average is 100, so that the averages are surely more reliable than any yet obtained. It may be possible that significant variations in weight may occur within a period of two or three weeks, without affecting the *monthly averages*. If these significant variations occur chiefly in the month of October, this might account for the lower average weight of the male-bearing ewes at the end of September. The only difference that I can observe is this, that the male-bearing ewes increased in weight at a greater rate than the female-bearing ewes during the month of October. They started lower and reached the same point by the end of the month. The difference, however, is so slight that it may not be significant.

"The only way to ascertain whether there is any real difference in the average weights of the two classes of ewes (male-bearing and female-bearing) within a short period of time, two or three weeks, is to multiply observations at short intervals of time."

Having found the apparent result of the first calculation on determination of sex nullified by the addition of further data, Dr. Bell decided not to press the investigation of the influence of the same factor—special feeding—on the fecundity of the ewes, until he had larger figures on which to base his computations. On this point he noted:

"In order to examine the results as to twins I added together the weights of the mothers of lambs born during the decade 1890-1899, the year 1900, and the year 1901. A marked difference exists between the weight-curves for the two classes of ewes, twin-bearing, and single-bearing. In the case of the twin-bearing, however, the absolute numbers involved are too small to make me certain of my results, especially after the experience with the male and female-bearing. The maximum number of cases used in determining an average is only 88, and the minimum 50 cases. It would be well in this case also to have the average of at least 100 cases before announcing results."

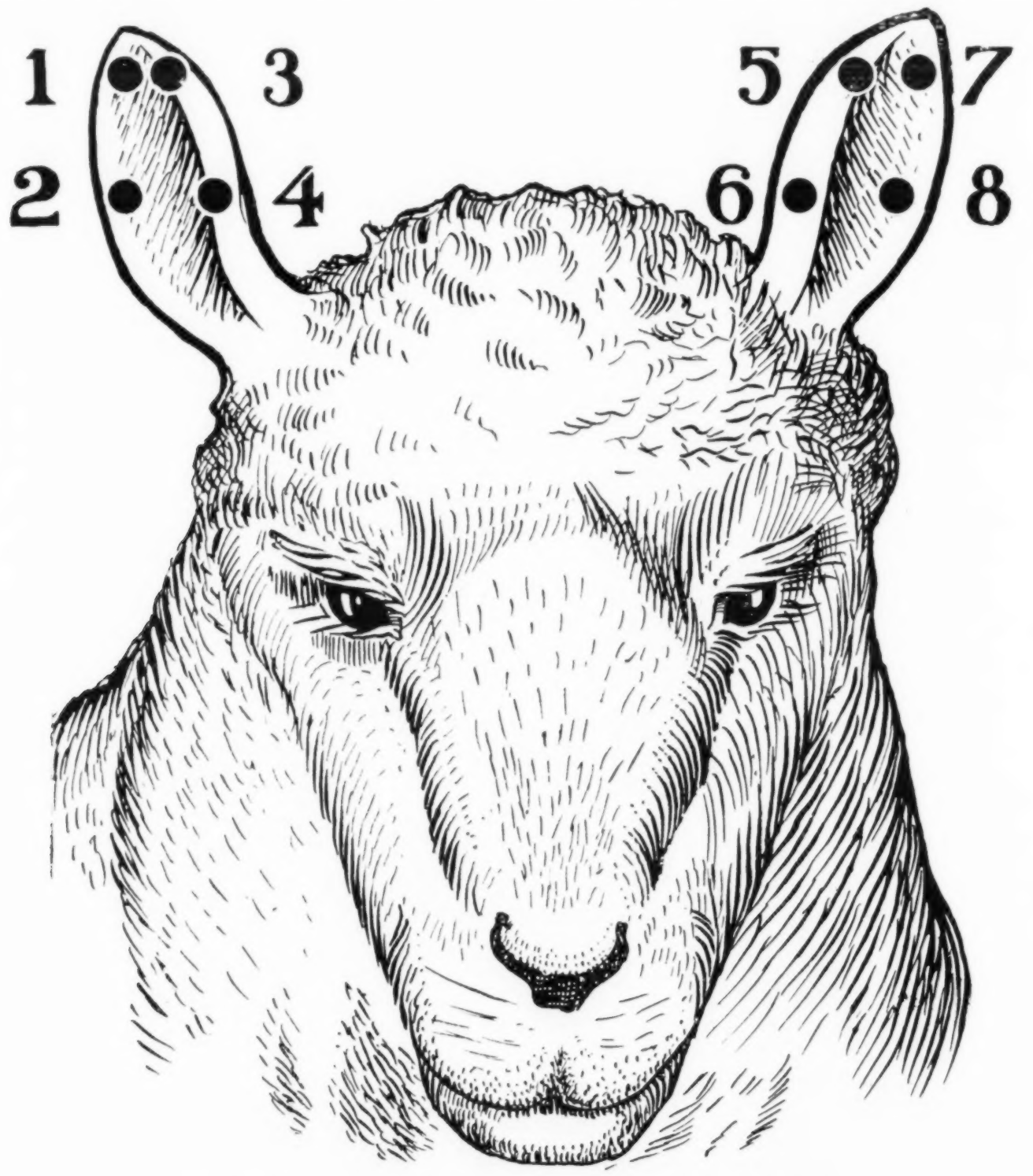
HANDLING THE MULTI-NIPPLED SHEEP

Dr. Bell's final decision to publish the results of the investigation was due partly to the belief that his own experience might serve as an example of the danger of drawing conclusions in such studies from anything but a large mass of data. The report has high value, however, merely as a

record of a carefully conducted experiment on an exceedingly interesting and much debated subject, and in this connection an account of the methods of weighing and feeding the sheep which took part should be of interest. The following account is taken from a report to Dr. Bell under date of September 10, 1908, made by Mr. J. C. Davidson, Superintendent of Beinn Bhreagh Nurseries, who has had charge of the flock for many years past:

"In former years it has been the custom every fall to do more or less extra feeding before or during the mating season. Hitherto this has all been done with the whole flock collectively. In the early part of the summer of 1907, discussing our arrangements for fall experiments, I referred to the fact that feeding of the sheep collectively did not give justice to all sheep alike, as some sheep, like every other animal, are gluttonous when they are fed anything suitable to their taste, and I suggested that we feed all sheep individually; which would necessitate the building of a barn for that purpose.

"Having a good idea of the amount of time experimental work of any kind consumes, I planned the feeding pens in circular form with a large circular box in the center to hold the feed, as a labor saving device. This enables a man to feed the entire circuit of the pens, which hold 19 sheep at once, in practically less time than it would otherwise take to walk from the feed



SHEEP WITH EARS FULLY PUNCHED

By the use of all of the eight positions for punched holes, as shown in the diagram, 256 sheep can be identified. In small experimental herds, it is usually necessary to use only a part of the positions indicated. The sheep can easily be identified in the field, if the shepherd walks in front of them and attracts their attention; they then raise their ears, and the holes punched can be made out readily. (Fig. 2a.)

room to the troughs in the ordinary way of feeding, besides having the great advantage of knowing that each animal, gets the same amount of feed placed in front of it; also if necessary, you know the exact amount each consumes, which might also be significant for various reasons. The individual feeding pens occupy the center of the building; on one end is a storeroom for feed, and on the other end is the weighing room; the latter also is an enormous time-saving device in comparison with the old method of having a weighing machine in every pasture enclosure.

FLOCK WEIGHED DAILY.

"A description of the daily handling of this experimental flock of multi-nippled sheep for a period of from ten to twelve weeks every fall may, to those who know the disposition of sheep,give some idea of the disadvantage this flock has in being disturbed at a time of the year when they would naturally be replenishing the lost energy they had sustained during the period of suckling their lambs.

"The sheep are collected from the pasture daily and taken to the barn-yard enclosures, and are driven into the weighing room,—or rather, if allowed, they rush—as after a day or two they know the performance as intelligently as their masters know it and become very anxious to get to this end of the building. The feed having already been put in the troughs of the different stalls, a man opens the door of the weighing box, and the sheep enter one at a time.

"Their ear marks, one, two, or three small punch holes, as the case may be, located in different positions in the ear, each hole at a given place, represent a figure from one to eight, which may also count twelve to eighteen or so on up into the hundreds. This is Dr. Bell's own invention of marking and does away with the use of collars or ear tags; and is also a sure means, to those familiar with the markings, of picking from large flocks any sheep that might get astray.

"The ear mark being called out, I examine same as a check. The ear mark number refers us to a different number which represents their register number. The sheep is weighed, weight recorded, and condition of wool or any irregularities noted. The door of the feeding stall being open in advance, a man opens the door on the side of weighing box and the sheep goes from weighing box to stall, door is closed and another opened, and by this time another sheep is weighed ready for next stall, where feed is consumed without disturbance and all share alike.

"It is very interesting to see how they keep their turns in going through the weighing machine, as after a few days the sheep that is weighed last, with few exceptions, will remain the last daily throughout the season; the whole performance passing off like clock-work. After coming from the feeding pens they are then visited by the male sex and any matings noted, which enables us to have an accurate record of father and mother, in every case. Besides, as the lambs come mostly in the cold month of March, we know when to look for them."

METHOD OF IDENTIFYING THE SHEEP

As the value of any experimental breeding with animals depends on an exact record of the individuals being kept, it becomes a matter of first importance to have a permanent and inalterable tag on each sheep. The ordinary tag fastened in the ear is easily torn out on wire fences, nor are collars wholly satisfactory.

After some experimenting, Dr. Bell devised a method of punch-marks in the lobes of the ears, which has proved quite satisfactory. Each lamb is marked before it is weaned, the ear being placed on a block of wood and an ordinary punch about one-fourth inch in diameter, with a hammer, used. The operation is all over before the lamb knows what is going on, and little pain is caused.

Dr. Bell described the operation, in a letter to a friend in 1910, as follows:

"Each ear of a sheep as it faces you presents two edges, an outer edge and an inner edge, on which holes can be punched in suitable positions to identify the sheep. As my flock is small, and simplicity is advisable, I do not find it necessary to distinguish more than two punch-places on the edge of the ear; one as high up as possible, the other as low down as possible. This gives us eight well marked places where holes can be punched. The shepherd is supplied with the accompanying diagram representing a sheep's head looking at him, and the punch-places are marked 1, 2, 3, 4, 5, 6, 7, and 8, as shown.

"Each sheep has a certain combination punched in the ears as an identifying mark. By punching only one hole in the proper place, we identify eight sheep. By punching two holes (for example, punch 1 and 2; 1 and 3; 1 and 4; 5 and 8; and so on) we can identify 28 sheep. By not limiting ourselves to any particular number of holes to be punched, we have the possibility of identifying 256 sheep. This being amply sufficient for any purpose, I have not found it necessary to distinguish more than two punch-places on the edge of each ear. I formerly tried three, one at the top, one at the bottom and one in the middle, but I found that my shepherd could not handle the system successfully, for it was often difficult to know whether a hole punched in the middle was intended to be above or below.

"For two years we have distinguished only two places on the edge of each ear. This has turned out to be perfectly satisfactory, for we can never mistake the upper hole for the lower, or vice versa.

"Given eight punch-places, as shown above, we can, by combinational punching, identify 256 sheep, as follows:

Total sheep identified by					0	hole	.....	1
"	"	"	"	"	1	"	.....	8
"	"	"	"	"	2	"	.....	28
"	"	"	"	"	3	"	.....	56
"	"	"	"	"	4	"	.....	70
"	"	"	"	"	5	"	.....	56
"	"	"	"	"	6	"	.....	28
"	"	"	"	"	7	"	.....	8
"	"	"	"	"	8	"	.....	1
Total sheep identified by 8 holes or less							.....	256

"For the purpose of identifying sheep that have lost their collars (I provide each sheep with a leather collar containing a metal plate riveted to it, bearing the name of the sheep), I have an index to the punch marks, and against the punch-mark I record the name of the sheep that bears that identifying mark. When a sheep dies, or is killed or sold, I scratch out the name of that sheep and give its punch-mark to another, so that during the two years that have elapsed since the adoption of the above system, I have only found it necessary to use 31 combinations out of a possible 256. I only mark these sheep that are kept; those that are to be sold are left unmarked."

In practice, this combination of punch marks is triplicated: that is, it is applied to white ewes, black ewes and rams, as there could be no possible confusion by having the same number used on both a white ewe and a black ewe. In this way, the number of positions which it is necessary to punch has been kept down. The use of collars on the sheep has now been abandoned, as the punch holes are found to meet every requirement of indentification.

LECTURER ON EUGENICS APPOINTED

A. Edward Hamilton of the Eugenics Record Office, Cold Spring Harbor, Long Island, N. Y., has been selected to serve in an educational capacity, and his services are available for lectures on eugenics before colleges, clubs, medical societies and other similar organizations. He is a graduate student of Clark University. Funds for this educational extension work were given to the Eugenics Record Office by Mrs. Huntington Wilson of Washington, D. C.

INJURIES TO GERM CELLS

Effects on Offspring of Intoxicating the Male Parent—Experiments Carried Through Several Generations Show that Results of Alcoholization are More Marked in Filial than in Parental Generation.

Abstract of an article in the American Naturalist by Dr. CHARLES R. STOCKARD, Cornell Medical College, New York City.[1]

Three years ago a series of experiments was begun with guinea-pigs in order to test the possibility of modifying the type of development in mammals, so as to produce definite monstrosities, as had been accomplished with lower vertebrates. This primary object has not been fully attained at the present time, yet the experiments have demonstrated several points concerning injury of the germ cells, and have shown that an alcoholized male guinea-pig almost invariably begets defective offspring even when mated with a vigorous normal female.

From the number of records available one might conclude that the effects of the alcoholic treatment were as pronounced upon the offspring of the second generation animals, although they had not been directly treated, as upon the offspring of alcoholized individuals. The poison injures the cells and tissues of the body, the germ cells as well as other cells, and the offspring derived from the weakened or affected germ cells have all of the cells of their bodies defective, both soma and germ, since each of the cells is a descendant of the injured germ cell combination. In this manner the defects or degenerate conditions are transmitted or passed to subsequent generations.

IN experiments to modify the germ cells of mammals the first proposition is to determine whether the substances used reach the germ cells directly. One of the best substances for such experiments is alcohol, since its action and distribution in the body have been largely studied and since it acts so decidedly to modify the developmental processes, as many workers have found on invertebrates, and as I have shown by treating fish eggs with this substance.

It is a well known and generally accepted fact that alcohol does cause changes and degeneration in many of the tissues of animals and man. The question arises, how, then, can the reproductive tissues, the ova and spermatozoa escape? Nicloux and Renault have found that alcohol has a decided affinity for the reproductive glands. In the testicular tissues and the seminal fluid an amount of alcohol is soon present which almost equals that in the blood of an individual having recently taken alcohol. The proportion of alcohol in the testis as compared with that in the blood was as two to three, and in the ovary of female mammals as three to five. From these observations it must follow that alcohol may act directly on the ripe spermatozoon shortly before it fertilizes the egg, and if this substance injuriously affects the germ cells, then one should expec to find an indication of he injury in the resulting development.

HUMAN CASES COMPLICATED.

There is an abundance of data bearing on the effects of parental poisoning on the human offspring, yet almost all of it is complicated. The question arises whether the defects of the offspring are actually due directly to the parental poisoning or to the often degenerate condition of the parent. With lower

[1] The detailed report of the experiment is in the American Naturalist, XLVII, Nov. 1913, from which this abstract is made.

HOW ALCOHOL STUNTS THE GROWTH

The guinea-pig at the left is a runt, because his father was alcoholic. He ought to weigh about 200 grams, but he weighs only 132. His mother was normal, and his degeneracy can, therefore, be traced with a good deal of certitude to the male parent. At the right is a guinea pig which, although only ten days older than the one at the left, is much larger in proportion, weighing 221 grams. His parents were both normal. (Fig. 3).

mammals this question may be controlled, since vigorous individuals with no physical weakness may be selected for study.

One of the most interesting human cases is that Forel cites as recorded by Schweighofer. A normal woman married a normal man and had three sound children. The husband died and the woman married a drunkard and gave birth to three other children; one of these became a drunkard; one had infantilism, while the third was a social degenerate and drunkard. The first two of these children contracted tuberculosis, which had never before been in the family. The woman married a third time and by this sober husband again produced sound children. This is a logical experiment,—the female was first tested with a normal male and gave normal children; when mated with an alcoholic male the progeny were defective. She was later tested again with a normal male and found to be capable of producing sound offspring. A number of such cases are on record but all are open to the question whether the defective offspring are actually due to the effects of the poison on the parent, or to the fact that the parent may have been weak and degenerate from the beginning.

ALL ANIMALS TESTED.

For our experiments to demonstrate the effects of alcoholization in guinea pigs, we take pains to select normal, healthy animals, and in all cases they are first tested by a normal mating in order to establish their ability to produce vigorous offspring. After such a test the treatments are begun. During the experiments the treated males and females are mated from time to time with normal animals, and in addition, control matings of normal individuals are made. Some of the specimens are treated with alcohol and ether. These substances were used since they readily act upon animal cells and since I had studied their effects on the development of fish embryos and found them to cause rather definite and easily recognizable defects in the central nervous system and organs of special sense.

In the beginning of the experiments alcohol was given along with the food, but the animals ate less and the food did not apparently agree with them. It was then administered in dilute form by a stomach tube; this method disturbed digestion and seemed to upset the animals considerably. It is certain that alcohol given to animals through the stomach deranges their digestion and appetite to such an extent that the experimenter is unable to determine whether the resulting effects are due to the alcohol, as such, or to the general deranged condition of the animal. When given in the drinking water they take little or none of the water and the treatment is insufficient. For these reasons an inhalation method of treatment has been resorted to which, as far as experience goes, has no serious disadvantages and does not complicate the conditions of the experiment.

METHOD OF INTOXICATION.

A fume tank of copper is made of sufficient size to supply breathing space for four or five guinea-pigs at one time. The tank is arranged with four outlets, so that definite amounts of the fumes may be passed through in a given time and the ventilation controlled. In this way each animal could be given about the same amount of the substances. The individuals, however, differ so in their resistance to the treatment that it has been found better to treat all to about the same degree of intoxication. This physiological index is more reliable as each animal is thus affected in a similar fashion each day. For this purpose they are placed in the fume tank on a wire screen, and absorbent cotton soaked with alcohol is placed beneath the screen, and the animals inhale the fumes.

Ether is given in a similar manner, except that the animals are much more readily overcome and must be carefully watched while inhaling even the most dilute doses.

In order to avoid handling the females during late pregnancy, a special treating cage is devised. An ordinary box-run with a covered nest in which the animal lives is connected by a drop-door with

a metal-lined tank, having a similar screen arrangement to that of the general treatment tank. The pregnant animal may be driven daily into the tank and thus treated with alcohol fumes throughout her pregnancy without being handled in any way that might disturb the developing fetus.

DIRECT EFFECTS OF TREATMENT.

Many of the animals have now been treated almost to the point of intoxication for six days per week for nearly three years. They are affected by the alcohol fumes in different ways; certain ones become drowsy and stupid, while others become excited and sometimes vicious during the treatment, constantly fighting and biting at others in the tank. One male always had to be treated alone on this account. The fumes are inhaled into the lungs and pass directly into the circulation, so that the animals show signs of intoxication very soon after being put into the tank, yet the intake of alcohol is so gradual that they may remain for one hour or more without becoming totally anesthetized. The mucosa of the respiratory tract is considerably irritated during the first few days or weeks of the treatment, but later becomes hardened and little effect can be noticed. The cornea of the eye is greatly irritated and often becomes milky white and opaque during the first few months; but later this clears up in most of the specimens and the animal is able to see perfectly, though one male that has been treated for 32 months is now entirely blind. The general condition of the animals under the treatment is very good; they all continue to grow if treated before reaching their full size, and become fat and vigorous, taking plenty of food and behaving in a normal manner in every particular.

Certain of the animals have been killed at different times during the experiment and their organs and tissues studied microscopically; all have seemed entirely normal. The tissues of one female were examined after she had been treated for over a year, and the heart, stomach, lungs, liver, kidney, etc., were all normal. She was generally fat but there was no fatty accumulation in the parenchyma of any of the organs except possibly a slight excess in the adrenal glands.

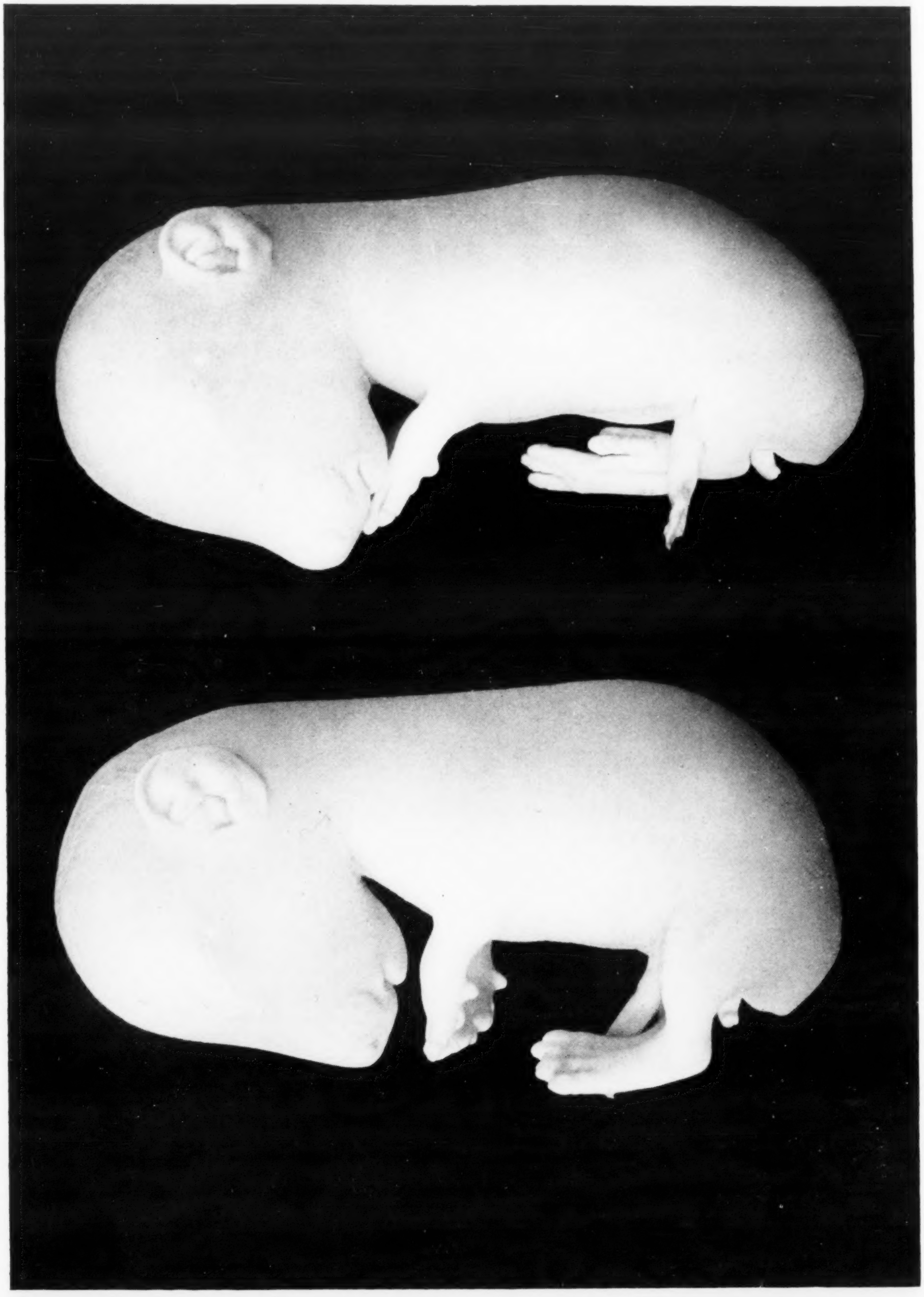
As mentioned above several of the animals, both males and females, have been partially castrated during the experiments and the ovaries and testis have been found to be in healthy condition.

The treated animals are, therefore, little changed or injured so far as their behavior and structure goes. Nevertheless, the effects of the treatment are most decidedly indicated by the type of offspring to which they give rise, whether they are mated together or with normal individuals.

The animals have been mated in various combinations. First, alcoholized males are paired with normal females, the paternal test, and also the crucial test of the influence of the treatment on the germ cells. Fifty-nine such matings have reached term. Twenty-five of these gave negative results or early abortions. Thirty-four of the fifty-nine matings resulted in conception which ran the full term. Eight, or about 24%, of these were stillborn litters containing in all 15 dead individuals. Many of them were somewhat premature. Twenty-six, or only 44%, of the matings produced litters of living young, containing a total of 54. Twenty-one, or almost 40%, of these young animals died within a few days or less than four weeks after birth and only 33 of them survived. Many of the 33 survivors are small excitable animals and though not treated themselves have usually given rise to defective offspring in the several cases where they have been mated with one another

WHEN FEMALE IS TREATED.

The second combination is between alcoholized females and normal males, the results of which are interesting in comparison with the above. In this combination there are two chances to injure the offspring; in the first place it may arise from a defective egg cell, or secondly, it may be injured by an abnormal developmental environment within the body of the alcoholized



TWO FOETUSES FROM A NORMAL MOTHER

The mother in this case was the offspring of a normal male and an alcoholized female. Although weak and small at birth, she finally developed normally. She was not treated with alcohol, but was mated to an alcoholized male. When she was accidentally killed, these two foetuses were found in her uterus—one 32 mm. long and the other 33 mm. The upper one has ill-formed hind legs, and a poorly developed posterior part of the body; the lower one is normal. It will be noted that all the affected offspring of alcoholic guinea pigs are weak in their hind extremities, and drag their legs; even to the point, as in this case, where the offspring of a normal mother is born deformed, through the influence of an alcoholic father and grand mother. (Fig. 4.)

female. Fifteen such matings have been made. Three of these, or 20%, gave negative results, or were possibly aborted very early. Three stillborn litters of nine individuals were produced. Sixty per cent. of the matings gave living litters, as against 44% in the first combination between treated males and normal females. The proportion of surviving young is, however less from the treated females than from the treated males. Of 19 living young nine died soon after birth and 10 survived.

BOTH PARENTS ALCOHOLIZED.

The third combination was between alcoholized males and females. Twenty-nine such matings gave in 15, or more than 50 per cent., of the cases negative results or early abortions. Three stillborn litters occurred, each consisting of two individuals. Only 11 living litters were produced containing 16 young, nine of which survived while seven died soon after birth.

All of the matings of the treated animals may be combined and compared with control matings as follows: In a total of 103 full term matings,43, or almost 42%, have given negative results or early abortions, while 35 control matings failed in only two cases, or about 6%, to yield a full term litter. Fourteen, or 13½%, of the matings gave stillborn litters consisting of 30 dead individuals. Only one stillborn litter occurred in the 35 control matings; this was a large litter of four individuals and the mother seemed almost unable to carry them. The 103 matings gave only 46 living litters, about 45%, while 32 living litters, or 91½%, were pro- by the 35 control matings.

The 46 living litters from the alcoholic matings contained 89 young, 37 of which died shortly after birth and 52 survived. The 32 living litters from the normal animals consisted of 60 individuals only four of which died while 56, or 93 %,of them survived.

Of 119 full term young, living and stillborn litters, produced by the alcoholic animals only 52, or less than 44%, survived as against the 56, or 87½%, survivors among the 64 full term control offspring.

The offspring derived from the alcoholic individuals are termed second generation animals and were not themselves treated with alcohol. In three cases second generation individuals have been mated with normal and have given perfect results, although the litters have been small. It might seem as though the normal mate possessed a strong tendency to counteract any defect which may have been present in the second generation animal.

Mating second generation individuals with alcoholized guinea-pigs gave very different results. Two out of three such matings produced stillborn young, one of which was grossly deformed. The third mating gave two surviving young.

Nineteen matings have been made between second generation animals, the outcome of which compares very unfavorably with that from the control matings, while the data are closely similar to those obtained from the alcoholic matings. Seven, or almost 37%, of the matings gave negative results. Twelve living litters were born consisting of 19 individuals, six, or about 32%, of which died very soon after birth and showed various nervous disorders; one was entirely eyeless and decidedly deformed.

These are the initial experiments with mammals to show *that an injury of the germ cells may express its effect on the offspring and be passed through subsequent generations.*

A STRIKING CASE.

The actual outcome of the experiments may be more fully recognized by a consideration of one of the most striking cases. A large normal female, weighing about 700 grams, had given two normal young by a control mating and had since given non-viable young by a mating with an alcoholic male. She was then mated with another large strong alcoholic male which weighed 740 grams and which had given before this mating apparently healthy offspring by normal females. The mating resulted in the production of four young, all small and rather excitable in their behavior. These individuals from the normal mother and the alcoholized

father grew slowly, although they ate freely and appeared to be well. They remained small and below the average in weight. Three were males and one was a female.

One of the males was mated with a normal female and two normal young resulted. He was then mated with a female from an alcoholic father and she gave birth to two small young; one of these offspring was only half size and very excitable. He was then mated with a female from an alcoholic mother and one small young was produced.

A second one of the three males was mated with a normal female which produced one large apparently normal offspring. He was then mated with a female from an alcoholic father and two small young resulted, one of which died within five days and the other is weak and nervous. He was again mated with a normal female and one normal young was produced.

The third male was mated with his sister and she gave birth to three young. One of the young died when one day old, having been in a constant tremor since its birth; another lived for nine days but whenever it attempted to walk it was seized with spasmodic contractions; the third specimen exhibited the same nervous manifestations and was completely eyeless. This animal died eight days after birth and an examination of the brain showed an entire absence of optic tracts.

In the development of this animal it is probable that the optic vesicles were suppressed and never arose from the brain. Thus, no eyes, optic nerves, or optic tracts could have formed. This particular eyeless condition in these experiments is of interest since one is readily able to suppress the origin of the optic vesicles in fish and chicken embryos by similarly weakening the embryo with treatments of alcohol, ether, etc.

The mother of these offspring was remated with her brother, but she died six weeks later, not becoming pregnant. She was in an emaciated condition but had always been less than half normal weight.

The three extremely weak and defective offspring were doubtless due to the fact that both of their parents had similarly weakened or injured constitutions, having resulted from a single mating of a normal female with an alcoholized male. The eyeless offspring and the other two nervous non-viable individuals should not be interpreted as due merely to the fact that their parents were brother and sister. Several normal matings of brother and sister have been made during the experiment and perfectly healthy offspring have been produced. In the studies of heredity conducted on guinea-pigs brother and sister are crossed with impunity, in no way weakening their offspring. The significant point in the present consideration is that the two animals coming from the same mother and treated father may have had similar weaknesses or defects and the combination of two such individuals resulted in offspring which exhibited these defects to a more decided extent. The three animals were far more defective than their parents and owed their defects to the modified condition of the germ cells of the grandfather from which they descended.

PLANT BREEDING SECTION TO MEET

A meeting of the Plant Breeding Section of the American Genetic Association will be held on February 20 and 21, in connection with the National Corn Exposition at Dallas, Texas. It is open to all members of the association, and contributions will be welcomed. Those who wish to send or read papers should communicate the titles at once to C. P. Bull, secretary of the exposition, at Dallas, together with an estimate of the length. Other information can be secured from A. W. Gilbert of Cornell University, chairman of the research committee on plant breeding.

A STUDY OF SEMI-STERILITY

Hybrids with Half their Pollen and Ovules Sterile—Semi-Sterility Inherited in Half of the Second Generation—Progeny of Fertile Plants Remains Fertile—Progeny of Semi-Sterile Plants is Half Fertile and Half Semi-Sterile—A Demonstration of Gametic Segregation—A Theory of Semi-Sterility.

JOHN BELLING,
Florida Agricultural Experiment Station, Gainesville, Fla.

HYBRIDS between two allied species of plants are often partially sterile. In three hybrids I have completed an investigation of the exact degree of such sterility, and of the inheritance of such an exact degree of sterility in the succeeding generations. I have found what I regard as proof of the causing of a definite degree of sterility by the segregation of Mendelian factors among the pollen-grains and embryo-sacs, and the consequent *abortion of a definite percentage of these*.[1] The following brief description of the results may, I hope, be of use to plant breeders.

The plants crossed were species of Stizolobium. The Florida Velvet "bean" (*S. deeringianum*) was crossed (both ways) with the Lyon "bean" (*S. niveum*) a variety introduced from the Philippines, and the fifth filial generation (F5) has been grown. The Velvet bean was crossed with the Yokohama bean (*S. hassjoo*), and the second filial generation (F2) has been investigated. The Velvet bean was also crossed with the China (or Chinese) bean (*S. niveum* var.), of which cross only the first generation has yet been studied. Fig. 5 is a photograph of typical five seeded pods of the Velvet, Lyon, Yokohama, and China beans. When seeds are missing in these pods, this is usually due to the ovules dying before maturity, and not to the abortion of embryo-sacs.

FIRST GENERATION HYBRIDS.

The hybrid plants resulting from these crosses were *all* similar in one important respect, namely, semi-sterility. Though the pollen-grains of the four parent plants are, under normal conditions, all sound; though their ovules have normally perfect embryo-sacs; yet this was not the case in the F1 hybrids. The flowers of these hybrids had uniformly one-half of their pollen-grains quite empty and collapsed, and one-half of their ovules had *no* embryo-sacs. In the F1 hybrid of the Velvet by China, counts gave 3917 perfect pollen-grains to 3388 empty grains. Some of the empty grains are often hidden under the full ones, or swept to one side by the liquid in which the pollen is spread under the microscope, so that it is probable that the number of empty grains is larger than the actual count. Fig. 5a is a photograph of the pollen.

Counts of ovules in sections of 18 ovaries, from flowers of the same hybrid, gave 50 ovules with embryo-sacs, to 49 ovules with aborted embryo-sacs, proportions which were confirmed by examination of the pollen and ripe pods of the other hybrids. The empty pollen-grains were uniformly mixed

[1] Detlefsen's valuable investigation in American Breeders' Magazine, III. 4, pp. 261-5, of the inheritance of sterility in crosses and back-crosses between the guinea-pig and a wild Cavia, may, I think, be explained on the hypothesis of the segregation of factors among the spermatozoa, and the consequent abortion of those spermatozoa with certain factorial combinations; but I do not know whether this can be scientifically proved from the data.

WIDE GROUP OF BEANS EMPLOYED

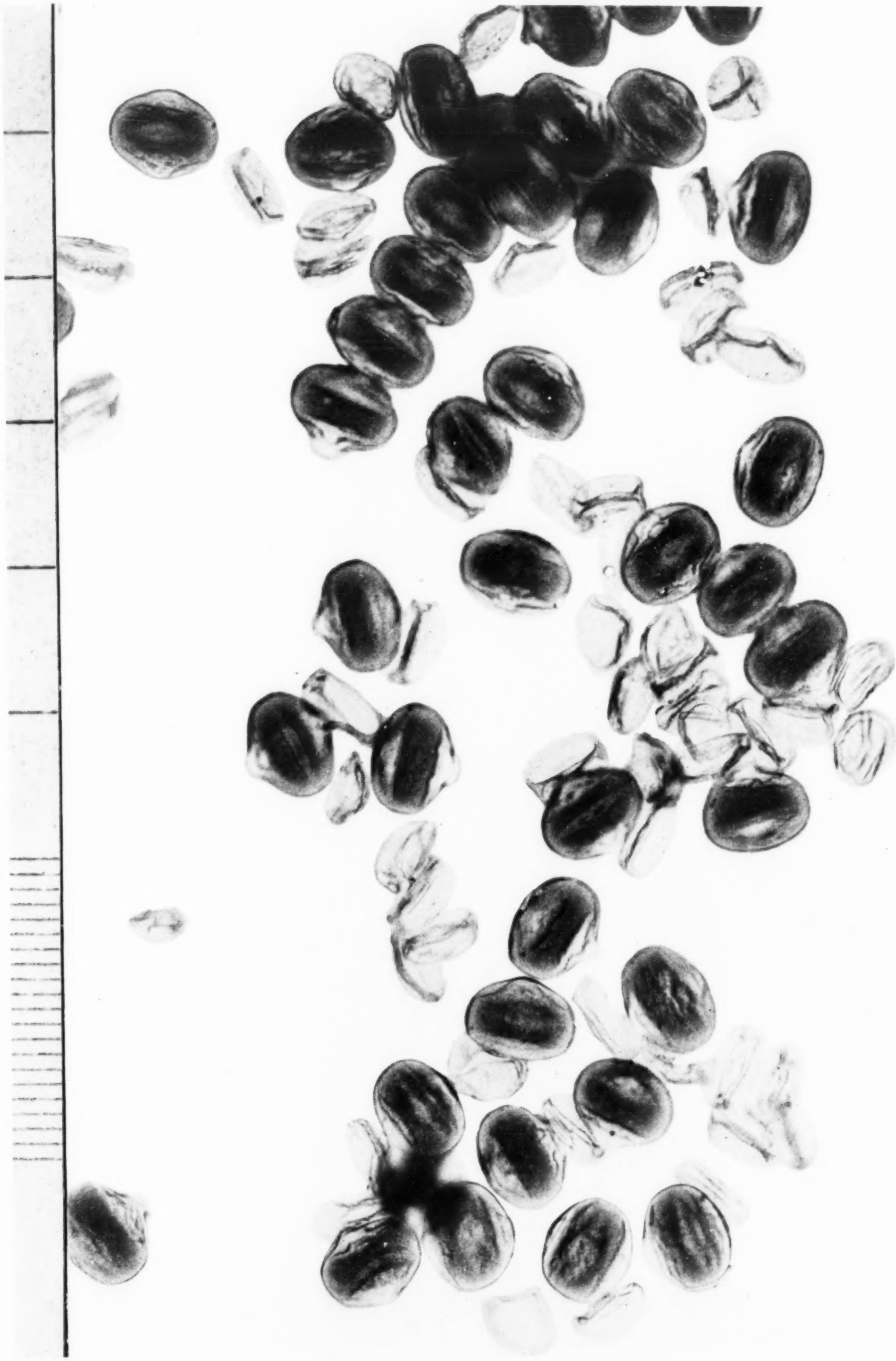
From left to right, the pods represent the ordinary Florida Velvet bean (*Stizolobium deeringianum*), the Lyon (*S.niveum*) a form which was introduced from the Philippines by the Department of Agriculture; the Yokohoma (*S.hassjoo*), a Japanese variety; and the China (*S.niveum* var.). The genus producing these "beans" is found in nearly every part of the tropics; its species can be divided into two groups—those which produce stinging hairs, and those which do not. The latter type is cultivated as a fodder, or to enrich the soil; its pods are eaten by the natives of India and other countries. (Fig. 5.)

with the full grains in the anther; and the sterile ovules were distributed at random in the ovaries. The ovary usually contains five or six ovules (rarely four or seven). A random distribution, such as would be caused by the segregation of Mendelian factors, and by no other cause known to me, would give for five ovules, (counting from the tip of the ovary) and 18 ovaries:

	Sterile	Fertile	Calculated	Found
No. of ovaries with.....	5	0 ovules	0.6	1
.....	4	1	2.8	1
.....	3	2	5.6	7
.....	2	3	5.6	5
.....	1	4	2.8	4
.....	0	5	0.6	0

A random distribution would give equal numbers of fertile and sterile ovules for each position in the pod, counting from the tip. The actual numbers are:

	1st.	2nd.	3rd.	4th	5th.	6th.
Fertile.....	12	9	10	6	9	4
Sterile.....	6	9	8	12	9	5



POLLEN GRAINS OF SEMI-STERILE PLANT.

This remarkable photo-micrograph of pollen grains of a first generation Lyon x Velvet hybrid shows strikingly the nature of the sterility, half of the sacs being empty. It was made by staining the pollen yellow and then photographing it with blue glass on the condenser. The size of the grains can be accurately measured by the scale at the side of the photograph, which is graduated in tenths and hundredths of millimeters. (Figure 5a.)

THREE FIRST-GENERATION HYBRIDS

From left to right the pods represent the results of crosses of Lyon by Velvet, Velvet by Yokohama, and Velvet by China, respectively. It is easily seen that these pods contain only half the normal number of seeds—that is, they are semi-sterile, in spite of the fact that all the pollen grains of their parents are normally sound and their ovules have normally perfect embryo-sacs. In the hybrids shown above, the semi-sterility is found, by microscopical examination, to result in one-half of their pollen grains being empty and collapsed, and one-half of their ovules being destitute of embryo-sacs. (Fig. 6).

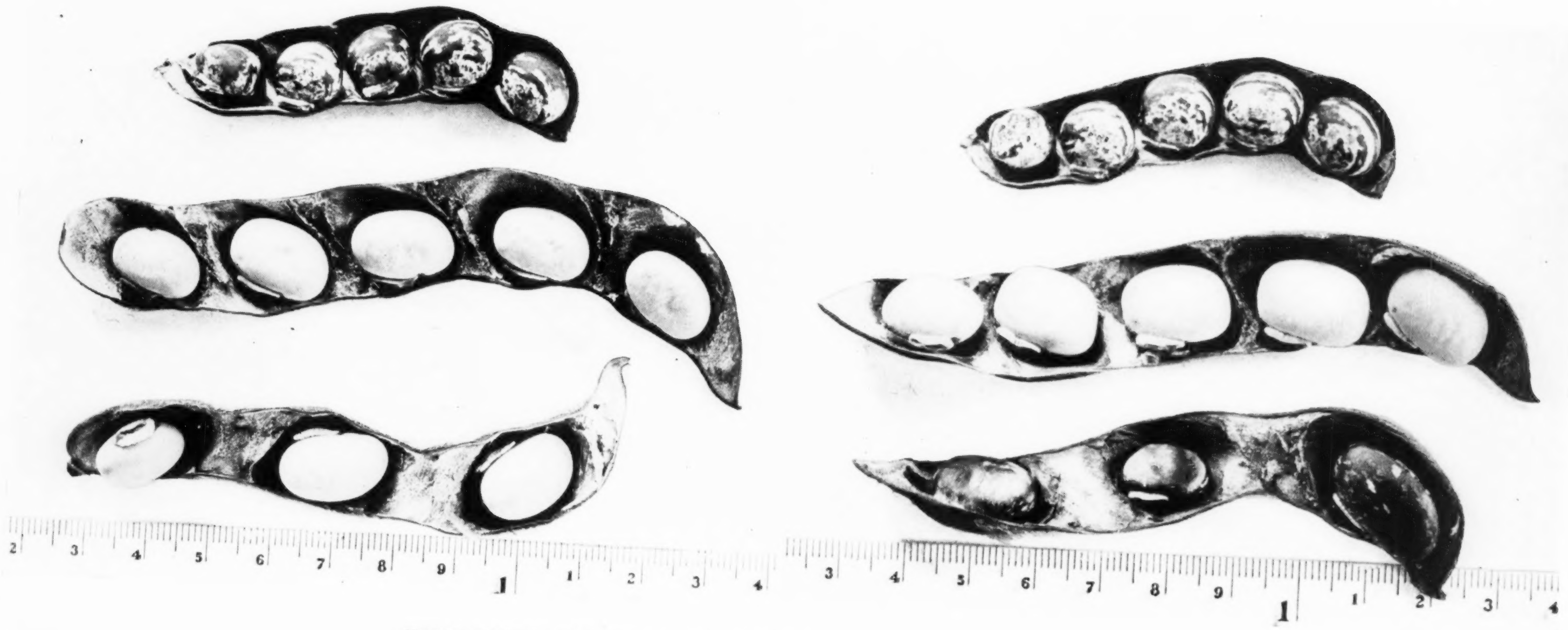
The agreement is as near as is to be expected with only 18 ovaries.

The sterile ovules do not grow in size, and the place where they are can usually be seen as a constriction from the outside of the pod. On opening the ripe pod, the aborted ovules are seen as blackish specks, less than one millimeter across. It is rare to find pods containing as many as five or six *seeds* in the hybrid (F1) plants, though this is a usual number in the parents. The seeds in the hybrid pods are as well formed, and germinate as readily as those of the parent plants.

Fig. 6 shows three selected pods of the Lyon by Velvet, the Velvet by Yokohama, and the Velvet by China, first-generation hybrids. Only about one or two per cent of the pods of these hybrids have no aborted ovules; some pods have several aborted ovules, some have few, but the commonest numbers are two or three. I have usually chosen pods for illustration in which aborted ovules alternate with seeds, but it is as common to find two aborted ovules or two seeds contiguous.

Fig. 7 (left) depicts pods of the Velvet, Yokohama, and their first-generation hybrid. Three aborted ovules can be seen in the hybrid pod.

Fig. 7 (right) illustrates pods of the Velvet, China, and their first-generation hybrid. The positions of two aborted ovules are visible in the hybrid pod.



TWO FIRST-GENERATION HYBRIDS AND THEIR PARENTS

Two species of beans, each bearing pods normally containing five to six seeds, are crossed. The resulting plants bear pods containing not five to six seeds, but only half that many. This is a phenomenon familiar to genetists, and represents one phase of one of the great problems of genetics—sterility. Mr. Belling thinks that the laws underlying the phenomenon can be studied to better advantage in these species of Stizolobium than in most plants, or any animals, and he has been working with large numbers of them to determine the arithmetical quantities involved. In the above photographs of two results, with a millimeter scale, the opened pods at the left are (from above downward) Velvet Yokohama and their first-generation hybrid. At the right again from the top downward, are opened pods of Velvet, China, and their first generation hybrid. In the hybrid at the lower left, the positions of three aborted ovules can be seen, while in the one at the lower right the positions of two aborted ovules are plainly visible between the seeds. The seeds which grow at all are as well-formed, and germinate as readily, as those of the parent plants, but the sterile ovules, making up half of the total number (on the average) are found, on opening the pod, to be nothing but blackish specks, less than one millimeter wide. (Fig 7.)

SEMI-STERILITY IN THE SECOND GENERATION

At the left are four typical, five-seeded pods from four fertile plants with normal pollen, from the second generation of Velvet by Yokohoma. The four pods on the right are taken from four other plants of the same generation and cross, but are all only half-filled with seeds. It will be remembered that, while in the first generation all the pods were semi-sterile, in this second generation half of the plants develop full pods like those at the left, while the other half of the plants are again semi-sterile, with the result shown in the four pods on the right, where half of the ovules will be found, on opening the pods, to be aborted. These last four plants had semi-sterile pollen. (Fig. 8).

THIRD GENERATION FROM FERTILE PARENT

This photograph represents pods from six plants of the Lyon and Velvet third generation (F3), grown from seed of a wholly fertile F2 plant, which was in turn grown from the seed of a semi-sterile F1 plant (all of the F1 generation being semi-sterile, of course). The above pods may fairly be taken to stand for the produce of half of all the plants of the third generation: they all have normal pollen and ovules, because they were produced by a F2 plant which was fertile. In each generation, fertile plants give rise to fertile plants; semi-sterile plants give rise to plants which are half fertile and half semi-sterile. (Fig. 9).

SECOND FILIAL GENERATION.

In the second generation (F2) half the plants have perfect pollen-grains, and the other half have a mixture of equal numbers of full and empty grains in *all* their flowers. The plants with perfect pollen have also perfect ovules; the plants with semi-sterile pollen have also half their ovules sterile. In the F2 generation of the Velvet-Yokohama cross, which was thoroughly investigated, there were 180 fertile plants and 195 semi-sterile plants. Counts of the numbers of seeds in the pods of the second-generation plants of Velvet by Lyon and Lyon by Velvet confirm this ratio of 1:1.

Fig. 8 (left) shows typical five-seeded pods of four fertile plants with normal pollen from the second generation of the Velvet by Yokohama cross. It will be remembered that half of the plants of this generation were normal, and half were semi-sterile.

Fig. 8 (right) shows selected pods of four fraternal plants of the same cross and generation as the plants whose pods are shown in Fig. 8 (left). These four plants, however, had semi-sterile pollen.

THE THIRD GENERATION.

In the third generation (F3) *all* the descendants of fertile plants have good pollen and ovules; but the progeny of the semi-sterile plants again separates into equal numbers of fertile and semi-sterile plants. In the F3 generation of the Lyon by Velvet cross, which was thoroughly investigated, the progeny of 14 fertile plants amounted to 264 plants, all with good pollen and ovules;

THIRD GENERATION FROM SEMI-STERILE PARENT

The opposite cut showed the product of fertile F2 plants; this one shows the product of semi-sterile F2 plants, in the same cross, Philippine Lyon by Florida Velvet. The plants which bore the above pods are first-cousins of the ones which bore the pods on the preceding page. These were all the product of one semi-sterile F2 plant, which was in itself the product of the usual semi-sterile F1 plant. As is evident, half of these plants bore pods, represented by the three at the left, which contain the full complement of beans; the other half of the plants produced pods typified by the three at the right, which are again semi-sterile, and contain only half as many seeds as they would have, if all their ovules were properly developed. The first three of these plants had normal pollen; the second three had semi-sterile pollen. (Fig. 10).

the progeny of seven semi-sterile plants consisted of 106 fertile plants and 102 plants with semi-sterility of pollen and ovules.

Fig. 9 is a photograph of pods of six third-generation plants. These belonged to the family of one fertile second-generation plant. All had normal pollen. They descended from the Lyon by Velvet cross.

Fig. 10 (to be compared with Fig. 9) gives the pods from six third-generation plants (first cousins to those in Fig. 9). These belonged to the family of one semi-sterile second-generation plant. The first three had normal pollen, the last three had semi-sterile pollen.

FOURTH AND FIFTH GENERATIONS

No semi-sterile plants have been tested beyond the third generation, but fertile plants remain fertile in pollen and ovules in F4 and F5. Several acres of those fertile plants which are of agricultural value have been grown in F5, and many flowers and pods examined, all of which were fertile.

In this investigation the pollen of over 2600 flowers has been examined under the microscope, and about 2300 young pods and 3700 dry pods have been opened, and the seeds and aborted ovules counted. In 1910, two acres of plants were grown; in 1911, the

experiment extended over nearly seven acres; in 1912, there were three acres; and in 1913 over two acres of individually numbered plants, and several acres of different families, were grown. The results given here are based on an individual study of over 2000 of these plants, grown eight feet apart, and (except in 1910) on eight-foot or four-foot poles.

These plants are favorable for an investigation of semi-sterility since no complications arise from self-sterility, incompatibility, or intercrossing by insects. Also the dry pollen is easily squeezed in a mass from the closed keel, and the seeds and aborted ovules can readily be counted in the dry pods as well as in the green pods. (Data with regard to one complication due to imperfect self-pollination and too short style will be given in a forth-coming paper).

The random abortion of half the pollen-grains and half the embryo-sacs, and the splitting of the progeny of the semi-sterile plants into half semi-sterile and half fertile, as well as the constancy of the fertile plants, agree in all details with a simple Mendelian hypothesis, in which the pollen-grains and embryo-sacs, not the zygotes, are the *individuals* affected by segregation. If the Velvet bean has a factor whose absence stops the development of those pollen-grains and embryo-sacs which lack it, and the other three allied beans have *another* similar factor segregating independently, then those pollen-grains and embryo-sacs of the hybrid which have *both* factors will be abnormal, because unlike the zygote, they normally have *single* and not *double* factors. Hence those pollen-grains and embryo-sacs which lack both factors, and those which possess both factors, alike fail to develop. This hypothesis can be verified or disproved by appropriate crosses between different fertile lines, which I hope to undertake.

THE POINTS OF INTEREST.

The following are noteworthy points:

(1) Accurate knowledge of the exact degree of sterility of some hybrid plants can be obtained by microscopical examination of the pollen of healthy flowers, and of microtome sections of the ovules.

(2) The explanation of the random abortion of half the pollen-grains and half the embryo-sacs must apparently be by the segregation of Mendelian factors among these individually, and *not* by the action of these factors on the zygotes.

(3) Semi-sterility resulting from crossing is apparently one of the simplest cases of sterility, and a knowledge of its inheritance may help in the investigation of the probably more complicated inheritance of the greater degrees of sterility found in many first-generation hybrids.

I wish to thank the Plant Physiologist of this Station, B. F. Floyd, for verifying my numerical results by an independent examination of the pollen-grains and the series of sections of ovaries of the hybrid (Velvet by China); and also C. D. Gunn, and C. W. Long, who have done much careful work, especially in counting seeds and examining flowers.

NOTE. I will send seeds of semi-sterile plants to any member of the American Genetic Association who may require them.

Neglected Opportunities

If a tenth part of the labor and cost now devoted by leisured persons, in this country alone, to the collection and maintenance of species of animals and plants which have been collected a hundred times before, were applied to statistical experiments in heredity, the result in a few years would make a revolution not only in the industrial art of the breeder, but in our views of heredity, species and variation.—William Bateson: Mendel's Principles of Heredity (1902).

A report from Berne, Switzerland, states that the Swiss Society of Public Utility for Women has established a bureau for the medical examination and certification of women for matrimony.

ORIGIN OF CULTIVATED OATS

Difference in Ancestry has Vital Bearing on Adaptability of Varieties—Forms Derived from A. Sterilis Best Suited to Southern Countries—Possibilities of Hybridization—Indication that Environment is Factor in Causing Variation—Influence of Culture and Result of Mutations

DR. L. TRABUT

Director of the Botanical Service of the Government of Algeria, Algiers, Algeria.

ALTHOUGH botanists have in the past usually considered that the many varieties of cultivated oat were descended from Avena fatua, *research has now proved that several species are to be found in the ancestry of these cultivated varieties, and particularly that those grown in the Mediterranean region mostly trace back to* Avena sterilis. *In future planting, therefore, and in attempting to extend the region where oats can be successfully grown, it is absolutely essential that regard be paid to the botanical affinities of the variety chosen, so that time and energy shall not be wasted by attempts to grow descendants of* Avena fatua *of temperate climates in subtropical regions where only* A. sterilis *will flourish, or in a dry region where* A. barbata *is best adapted to cultivation. The prevailing belief that oats can not be grown in the southern United States is probably based on the fact that all the experiments made there have been with cold-climate oats. A great deal of money has already been lost by such attempts, foredoomed to failure because of the unsuitableness of the material:—although suitable material might have been had, and the country's wealth thus enormously increased, had growers studied the genetic history of the cultivated oats earlier. From this point of view, the interesting studies of Dr. Trabut have such practical importance to plant breeders throughout the world that the council determined to republish them from the Proceedings of the Fourth Congress of Genetics, to which body they were communicated at the meeting in Paris in 1911. The translation is by S. C. Stuntz.*

In studying the section Euavena of the genus Avena with a little care, we are impressed with the great number of secondary forms which constitute the species, often living in the midst of cultivated crops in "outposts" established as a result of their wide dispersion outside of the region of their origin.

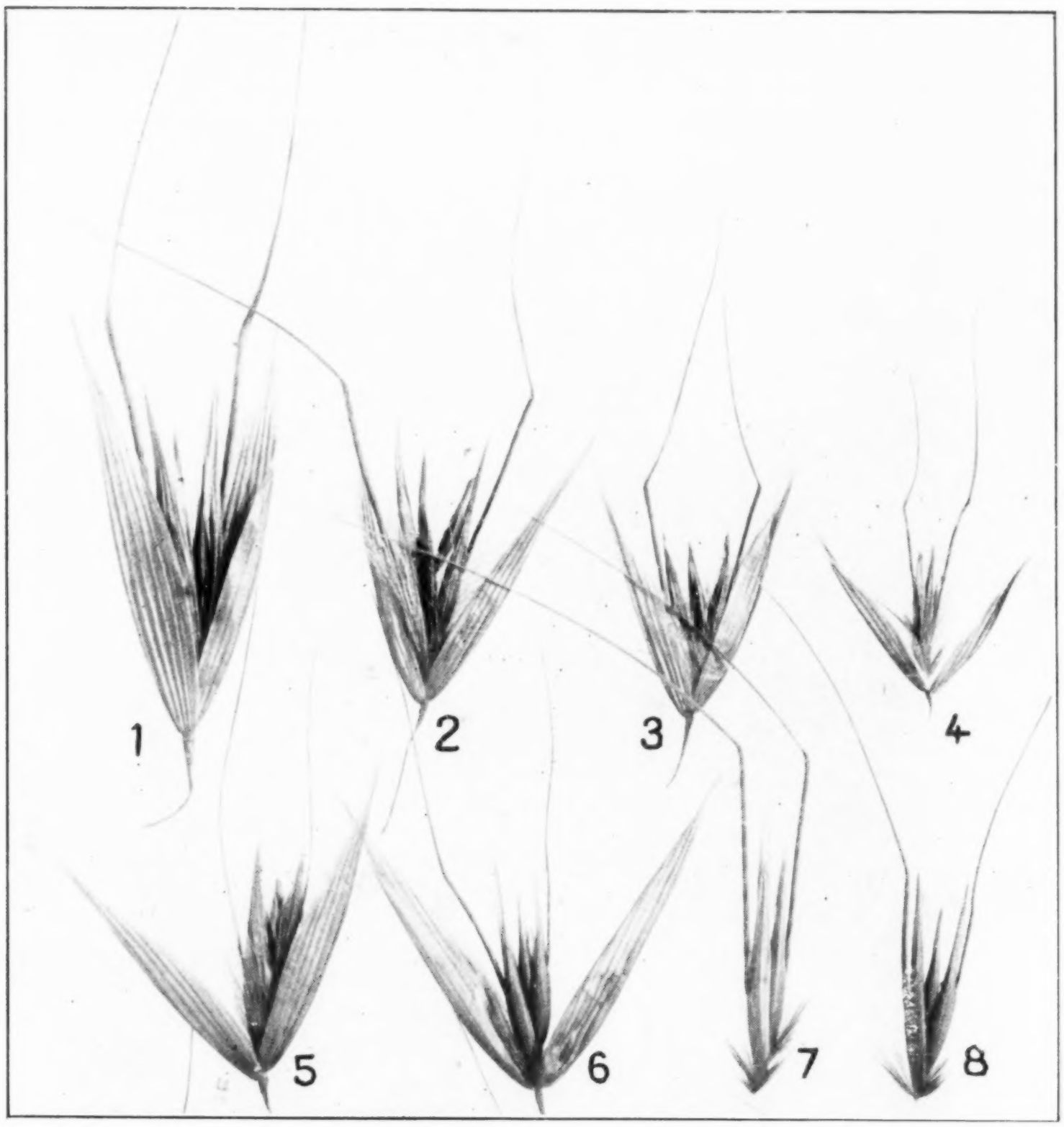
Without doubt these forms may be ascribed to the influence of cultivation, causing variations, or favoring forms which would not find place under the natural conditions of existence. I am even convinced that it is by this involuntary cultivation that man has caused the appearance of the useful races of the genus *Avena*.

But, not to depart from the realm of fact, we know that on the Mediterreanean litoral we are able to bring together the following very important series of *Avena sterilis*, beginning with the most useless forms and ending with an oat largely cultivated in the Mediterranean region, and up to the present wrongly confounded by both scientific and practical writers with *Avena sativa*.

COMPLETE SERIES OF FORMS.

Avena sterilis maxima Perez Lara, Fl. Gad. (fig. 11, No. 1). Inflorescence few-flowered. Spikelets very large, the glumes attaining 50 mm.; lemmae covered with long hairs, and bearing a strongly developed, geniculate and twisted, often hairy, awn.

A. sterilis segetalis Bianca, Todaro



SERIES OF FORMS OF "ANIMATED" OR "FLY" OAT

All of the above are merely varieties of *Avena sterilis*, and a glance at them, when they are side by side, shows plainly the mistake made by writers who considered the two extremes as separate species, making the Algerian oat a form of *A.sativa*, when it is really a form of *A. sterilis*, in which the awns have been reduced and the articulation consolidated through a complete series of intermediate forms. The varieties are as follows: 1. *Avena sterilis maxima*. 2. *A.sterilis*. 3. *A.sterilis ludoviciana*. 4. *A.sterilis micrantha*. 5. *A.sterilis segetalis*. 6. *A.sterilis pseudovilis*. 7. *A.sterilis calvescens*. 8. *A.sterilis pseudovilis*. (Fig. 11).

Exsicc. Sic. 712 (fig. 11, No. 5). Spikelets a little less voluminous, remarkable because of the great reduction of the not geniculate and barely twisted awn. Sicily in cultivated fields. A form very close to this is quite common in Algeria in cultivated fields; the seed is large and the lemmae are black.

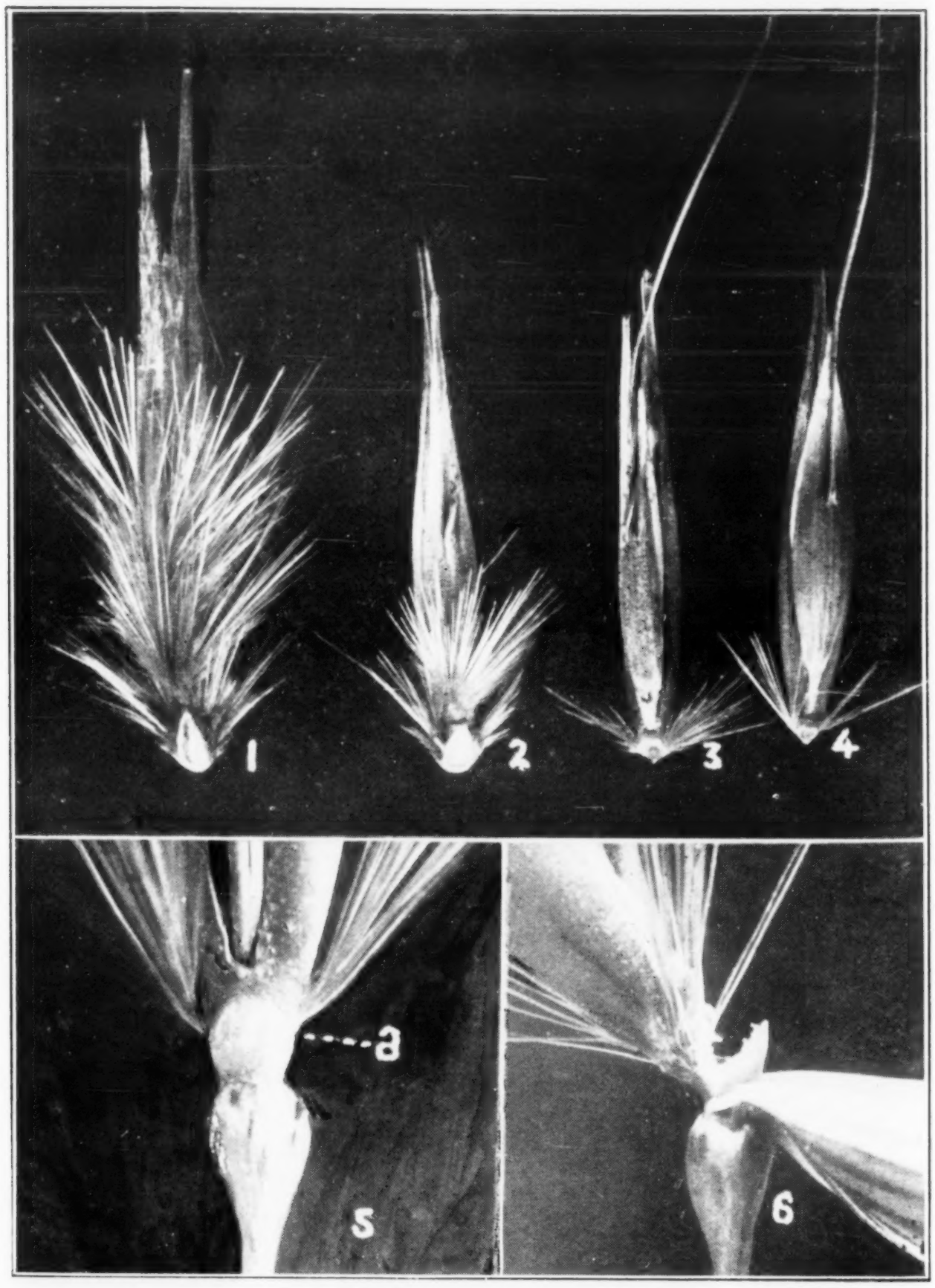
A. sterilis calvescens Trabut and Thellung, Vierteljahrssch. Naturf. Ges. Zurich, vol. 56, p. 315, 1911; *A. sterilis var. A.* Trabut (Compt. Rend. Acad. Sci., vol. 491 p,. 227-229, 1909). Lemmae coriaceous, glabrous, awn twisted, geniculate, but the callus still very hairy (fig. 11, No. 7).

A. sterilis pseudovilis Hausskn. Kritische Bemerkungen über einige Avena Arten, 1894. *A. sterilis var. B.* Trabut, *loc. cit.* This variety differs but little from the cultivated form in which no hairs are found except on the callus of the lower flower, the awns are reduced, but at maturity the spikelet separates very easily from the glumes (fig. 11, No. 8.).

THE ALGERIAN OAT

Above is a head of *Avena algeriensis*, a single spikelet of which is shown below, at the left. Next to this is a photograph of the grains shown in more detail, at the right of which the second seed is shown alone. On the extreme right of the photograph (lower section) is shown the product of an improved variety of this type. (Figure 12.)

A. sterilis byzantina (Koch) Trabut. *A. byzantina* Koch (Linnaea, col. 21, p. 392. 1848). *A. sterilis var. Y.* Trabut, 1910. B. A. Alg. Tunis. This form was described by Koch in 1848. M. Thellung has established the synonymy of this interesting variety. Cosson (Bull. Soc. Bot. France, vol. 1, p. 15, 1854) and the contemporary authors have referred *A. byzantina* Koch to *A. fatua*, more especially to the glabrous forms: *A. hybrida*, *A. fatua glabrescens* Cosson. Haussknecht published it as *Avena sterilis parallela* in 1885. *Avena sterilis*



ARTICULATIONS OF A. STERILIS

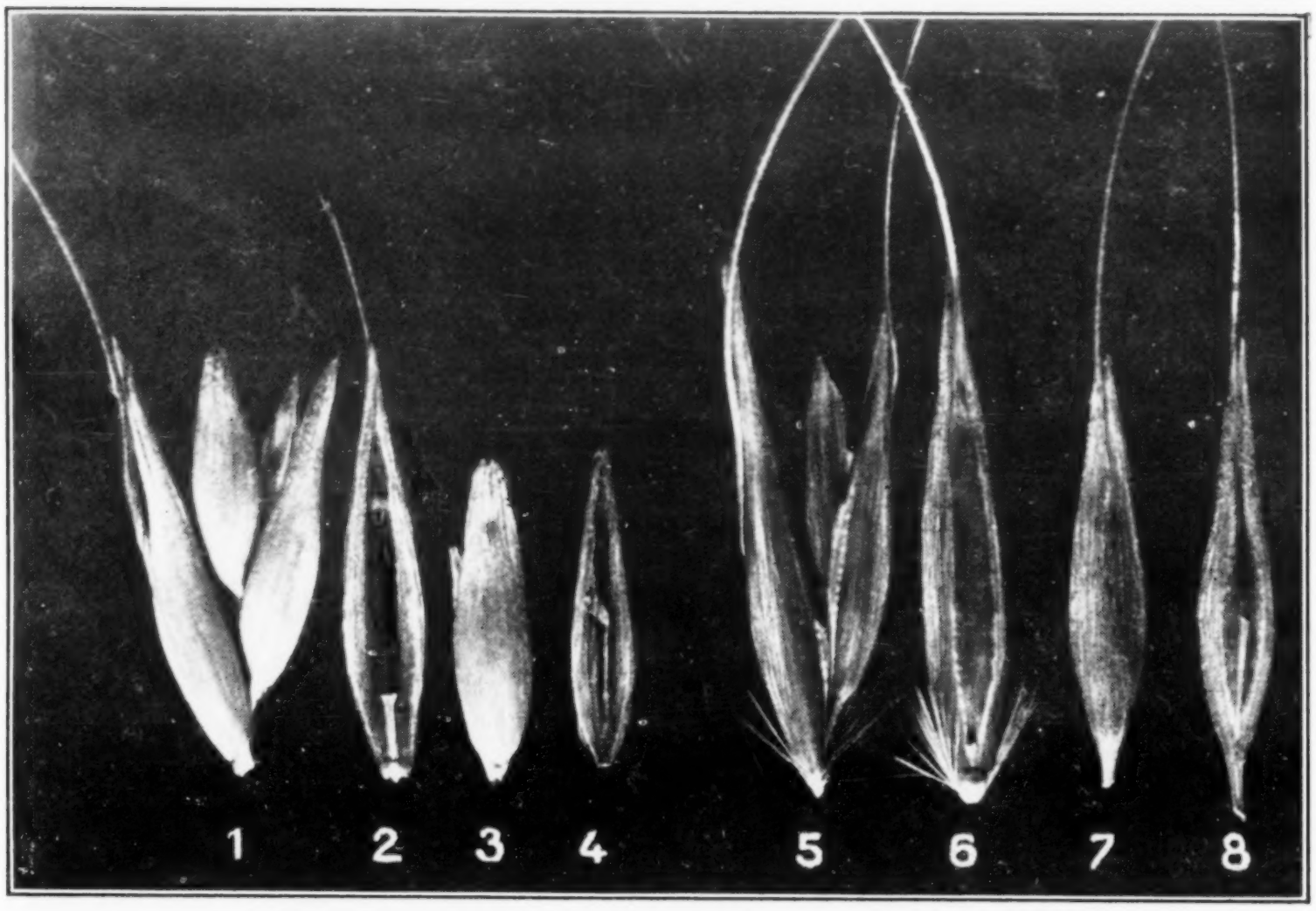
1. *A.sterilis maxima.*—2. *A.sterilis glabrescens.*—3. *A.sterilis byzantina.*—4. *A.sterilis culta.*—5. The same, viewed from the front.—6. The same, viewed in profile. The articulation is perhaps the most distinctive character of this species, and the progress of amelioration in the cultivated varieties simply leads toward a greater consolidation of the articulation. (Figure 13.)

byzantina has largely lost the characters of the sterilis type, and constitutes the last stage before reaching the cultivated form; the awn is reduced, the hairs of the callus are reduced, the articulation is still well preserved and the flowers fall easily at maturity, and the lemmae are also more lengthened than in the cultivated races. In 1907 M. Hackel wrote me that he considered this form as intermediate between *A. sativa* and *A. sterilis* and named it provisionally *A. sativa biaristata* (fig. 13, No. 3.)

A. sterilis algeriensis Trabut, 1910. *A. sterilis culta.* The Algerian oat is the cultivated form of the sterile oat. It is characterized by the reduction of the awn and the consolidation of the articulation.

THE ALGERIAN OAT.

The Algerian oat (fig. 12) is very widely distributed in the whole Mediterranean basin where it has long been recognized by growers: MM. Denaiffe



THE TWO SPECIES CONTRASTED

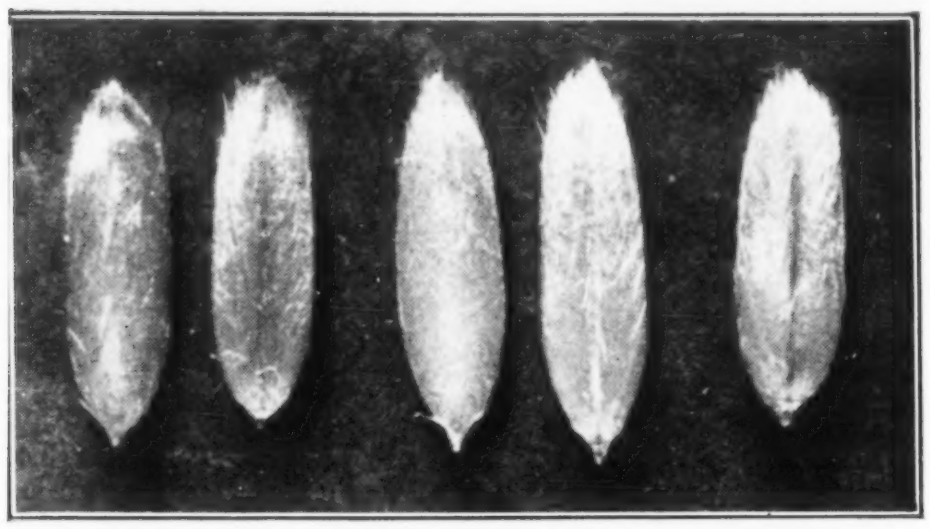
Nos. 1, 2, 3, 4, are the ordinary cultivated oat of temperate regions, *Avena sativa*. 1. The spikelet. 2. The lower flower with the fragment of the axis which bore the second flower. 3. and 4. The second flower, disarticulated. Nos. 5, 6, 7, 8 are the Algerian oat, a cultivated form of *A. sterilis*, which can be most easily distinguished by its method of disarticulation, in which the second flower carries away its own axis, as shown in 7 and 8. No. 6 shows the third flower without the second axis (compare with No. 2, showing the same flower in *A. sativa*), while No. 5 shows the whole spikelet of this Algerian oat. (Figure 14.)

and Sirodot[1] in their monograph on oats, in connection with the Abruzzi oat, indicate good characters and even propose to separate the Abruzzi oat and the Algerian and Tunisian oat as sections of *A. sativa*. Haussknecht, who studied the forms of sterilis very conscientiously, expressed the wish to see a useful race arise some day from this group which is so well adapted to the Mediterranean region; in 1894 in the Mittheilungen des Thüringisches Botanisches Vereins (n. f. no. 6, p. 39), he expressed himself thus: "For the countries of Southern Europe, *Avena sterilis*, improved by cultivation, on account of its larger yield, would produce a very desirable forage plant, especially where our *A. sativa* will not thrive well." If Haussknecht had had occasion to study the southern oats in the field, he would certainly have declared that his wish had for a long time been realized, and that his *Avena sterilis parallela* was nothing more than an escape from cultivation. The existence of a whole series of forms uniting the most characteristic *A. sterilis* with the oat which is cultivated in southern countries, is a strong chain which cannot be neglected, while a study of the morphological and physiological characters of the Algerian oat reveals affinities which no longer leave any doubt.

The section of *Avena sativa* characterized by non-articulate flowers which are separated only by the breaking of the axis, is based on an artificial character. It is because of cultivation that the articulations have ceased to function.

The group of *A. sativa* is made up only of the hairless and ankylosed oats of the other sections *biformes* and *conformes*. *Avena sativa* has retained all the characters of its ancestor, *A. fatua*. The second flower still separates easily from

[1]L'Avoine, pp. 181, 301, 1901.



THREE TYPES OF CARYOPSES

Reading from left to right, the first two are of *Avena sterilis maxima*, the third and fourth of *A. sterilis culta* (the ordinary Algerian oat), while the last, at the extreme right, is *A.sativa*, the ordinary oat of temperate regions. It will be noted that the caryopsis of the Algerian variety is as voluminous as that of the best races of *A.sativa*, but a little more lengthened. (Fig. 15).

the axis which persists above the lower flower, the articulation of the lower flower is more completely obliterated and it is a true rupture which permits it to separate from the glumes.

DISTINCTIVE CHARACTERS.

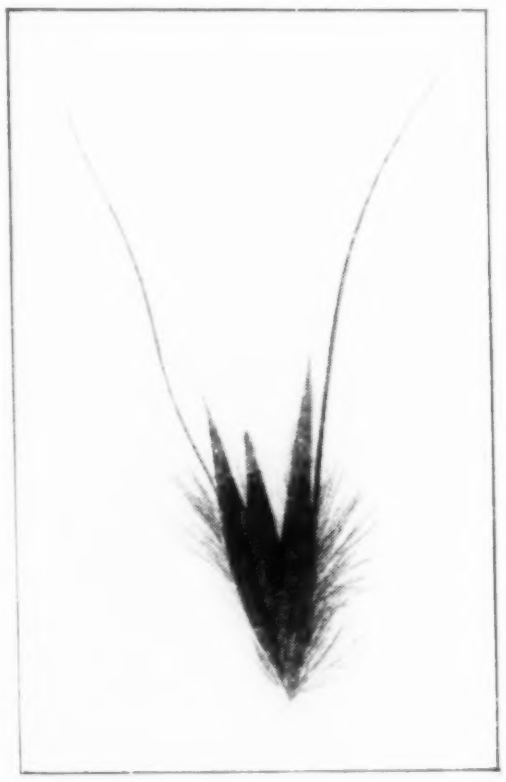
In the cultivated form of *A. sterilis* or Algerian oat, the basilar articulation is still very evident. The separation is not as easy in the cultivated race, as in the wild type, but the line of demarcation and the articular surfaces may easily be recognized. The second flower, which is not articulated in *A. sterilis*, as in *A. fatua*, remains adherent for a long time. It does not separate without carrying away at its base the axis itself, which constitutes one of its most characteristic points (fig. 14, no. 7). These two characters make it possible to recognize at sight the cultivated oats decended from *A. sterilis*, races which otherwise are very little different, and do not constitute so varied a series, as do the forms of *A. sativa* derived from *A. fatua*.

The caryopsis of the Algerian oat is as voluminous as that of the best races of *A. sativa*, but it is a little more lengthened (fig. 15, no. 2).

Avena sterilis culta has the panicles generally few flowered, of from twenty-five to fifty spikelets; it suckers more than *A. sativa*, and when cut green, the Algerian oat will even give a second crop with rather numerous full panicles.

The importance of this distinction, besides its interest as indicating the origin of one of our most widely cultivated plants, rests above all in the very peculiar aptitudes of the races derived from *A. sterilis*.

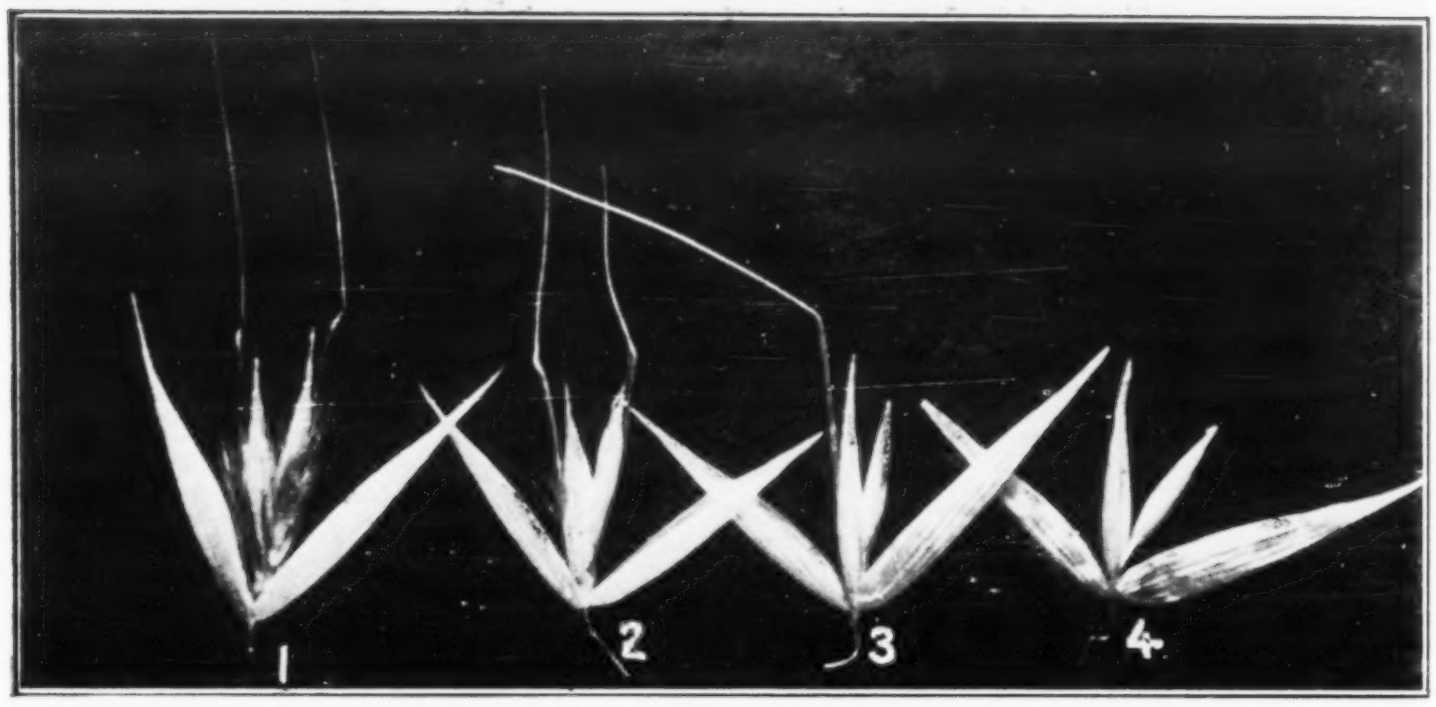
Since 1895, in the oat experiments undertaken at the Botanical Station[2],



A WILD BLACK OAT

This form of the Algerian species is sometimes found growing spontaneously. It has been named *A. sterilis segetalis f. nigra*, and a commercial variety has been produced from it, by selection to reduce the awns. It has been introduced to the United States. (Figure 16).

[2]Of Maison Carré near Algiers.



TYPES OF THE WILD, TEMPERATE OAT

Four forms of *Avena fatua*. 1. *A.fatua* itself. 2. *A.fatua glabrescens*. 3. *A.fatua subuniflora*. 4. *A.fatua subuniflora inermis*. The second has sometimes been supposed, without any proof, to be a hybrid of *A.fatua* and *A.sativa*. The third is found at considerable altitudes in Algeria, and sometimes presents awnless individuals (no. 4), which could easily be fixed to produce an awnless variety of this subspecies. (Figure 17).

I have proven that very few varieties give satisfactory results in cultivation along the coast. The few varieties which have resisted drought and rust were received under names Abruzzi oats, Naples oats, Tunisian oats, Spanish oats, Greek oats. They all have the same appearance and are practically indistinguishable. They are all *Avena sterilis culta*.

This type derived from *A. sterilis* does not seem to have acquired any other characters than very secondary ones; color more or less bright, awn more or less reduced, hairs of the callus more or less abundant. By careful segregation, a form with shorter grain, more swollen and of greater density (fig. 1, 2, no. 4) is obtained, but the lemmae remain hard, which is a very serious defect. A form with three grains may also be fixed.

ALKALI RESISTANCE.

The Algerian oat not only resists heat and rust, but also to a certain degree alkali in the soil. In the plains of Oran, very extensive growths of *A. sterilis ludoviciana* are often seen in saline places.

It is evidently from this form that it will be possible to obtain a race suitable for saline soils; there already exist glabrescent variations with reduced awns.

The results of my observations on the resistance of the Algerian oat, have, for a long time, attracted the attention of the experiment stations of Cape of Good Hope, Australia, and the United States, which have checked my statements and have made important distributions of seed of Algerian origin. The results obtained have been good.

From the point of view of genetics, it is interesting to show the great uniformity of *Avena sterilis culta*, while *Avena fatua sativa* has been almost overwhelmed by the multiplicity of its cultivated races.

I have tried hybridizing, after having shown that no cultivated form could be regarded as having the combined characters of the two species. It will be useful, by causing variations, to obtain the following modifications of the Algerian oat:

a) Reduction of the length of the lemmae. There already exist elementary forms showing this character, as well as the reduction of the awns.

b) Reduction of the hardness of the lemmae which make this oat less digestible. The weight of chaff in relation to kernel is nevertheless no higher in

TWO FORMS OF THE BARBED OAT

B The type (*Avena barbata*). It has given rise to a number of cultivated forms which seem especially adapted to dry regions. At the right (S) is one of these, *A.strigosa*, which has hitherto been grouped with *A.sativa*, but is merely a glabrous form of *A.barbata*, which has lost the fragility of articulations which characterize the latter. (Figure 18).

the Algerian oats. The proportion is, in harvests made under good conditions, 71% of kernels to 29% of chaff. But the experiments of Captain Bosnot, at the Horse Breeding Station at Tiaret, have shown that the Algerian oat has a coefficient of digestibility a little lower: thus with Houdan oats, 62 grams per kilo escaped digestion and with Algerian oats, 70 grams,—although the White Canada oat, in the same trials, has 75 grams not digested. Histological examination of the lemmae does not reveal any difference in thickness or consistency from those which are observed in *A. sativa*.

c) Selection by density quickly gives a practical result, perhaps still more evident in this species than in the ordinary oat.

d) The Algerian oat is of bright color, but there are also black races, derived from the black forms of calvescens and segetalis which are easily found at harvest time. *Avena sterilis segetalis f. nigra* (fig. 16) is such a race.

e) I have succeeded in fixing by selection a race of this oat having only a single awn, on the first flower, the awn on the second flower not developing.

DIFFERENCE IN DISTRIBUTION.

Avena fatua has a very different distribution from that of *A. sterilis;* this species is found on our high plains, the steppes or on the slightly humid Oranian and Tunisian littoral. Like *A. sterilis*, *A. fatua* presents numerous transition forms toward the cultivated type,—*A. sativa*.

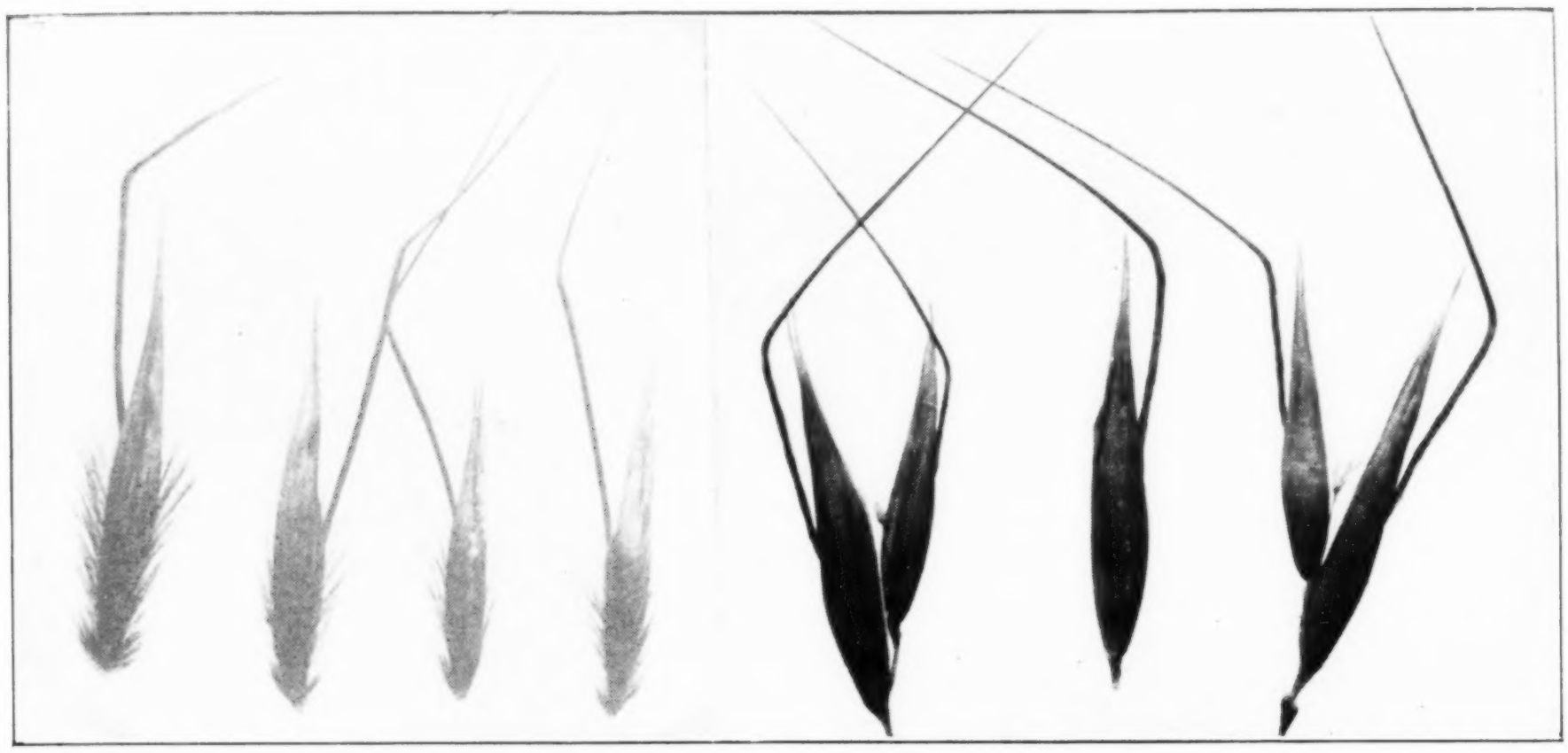
AVENA BARBATA TRIFLORA

A well-marked form of *A.barbata*. This species is found throughout much of northern Africa, the Abyssinian varieties being closely allied to it, if not identical. (Figure 19).

In 1854, Cosson (Bulletin de la Société Botanique de France, vol. 1, p. 15) distinguished an *A. fatua glabrescens* which merges with *A. hybrida* Peterm. (Flora Saxonica, p. 17, 1842). These forms have been regarded as hybrids of *A. fatua* and *sativa*, but without any proof. In the Sersou (altitude 1000 metres) I have found a link uniting *A. hybrida* with *A. sativa*.

This form (*A. subuniflora*) presents the general characters of *A. fatua;* but it is glabrous, the well indicated articulation functions badly, the second flower is most often abortive and the lower flower has a long twisted and geniculate awn (fig. 17, nos. 3–4) like the wild forms. In culture it maintains itself and presents at the same time some awnless individuals which it will be easy to fix. These transition forms are sometimes regarded as returns of a cultivated race to a wild state; this is possible, but it is certain that the supposed reversions of *A. sativa* lead toward *A. fatua*.

It is quite evident today that *A. fatua* has supplied the great majority of the cultivated oats brought together under the name *A. sativa*, and that it is still possible to bring together the whole series of intermediate forms between the wild type and the forms adapted to cultivation.



THE ABYSSINIAN OATS

1, 2, 3, 4, *Avena wiestii*, a hairy form growing wild in Abyssinia, and seemingly adapted to desert regions. 5, 6, 7, *A. abyssinica*, a cultivated form grown by the Abyssinians, not for grain, but for forage. In cultivation, all the transition stages between these two have been found. They offer a rich field to plant breeders, in the production of varieties of oat adapted to severe desert conditions. (Fig. 20).

OTHER SPECIES EXAMINED.

A. barbata. The creation by Linnaeus of an artificial species (*A. sativa*), comprising all the forms of Avena not disarticulating themselves, has for a long time misled searchers wishing to clear up the origin of *A. sativa*.

If we are able to admit as demonstrated that *A. sterilis* and *A. fatua* have transformed themselves into two cultivated oats, it remains for us to examine the other species to see if they have not undergone the same modifications by cultivation and if they have not become usable after having been weeds.

In examining *A. strigosa* Schreber, which has also been included with *A. sativa*, there is little delay in finding all the characters of *A. barbata*, not taking into account the functioning of the articulations and the pilosity, two fluctuating characters without value, as we have seen in *A. sterilis* and *A. fatua*. *A. strigosa* is indeed the glabrous form which has lost the fragility of the articulations of *A. barbata*.

Haussknecht (l. c. 1894, p. 20) has observed the intermediate form, var. *solida*, but it appears very rare. In examining a great number of plants of *A. barbata*, I have never found anything other than a three-flowered, robust form with large spikelets, different from *barbata triflora* Wilk, and from the two-flowered forms with lagre spikelets growing in grain fields.

In cultivating *A. strigosa*, I have obtained transition forms towards *A. barbata*, with the spikelets of the lemmae almost as pilose as in the wild type, but with more solid articulations.

A. brevis Rotl which has been described as a form of *A. sativa* is connected with *A. strigosa*, derived of course from *A. barbata*.

THE ABYSSINIAN OAT.

Avena abyssinica. My study of *A. barbata* for the Flore de l'Algerie led me to separate the southern forms and those from the Sahara under the names of varieties *fuscescens* and *minor*. Haussknecht has since (1894) identified these desert forms with *Avena wiestii* Steudel.

A. Wiestii differs little morphologically from *A. barbata*, but it is nevertheless a form interesting because of its habitat. In northern Africa, it appears very widely distributed in sub-saharan localities. In Cyrenaica, Taubert collected at Derna a form *solida* (exsicc. no. 507) which is the transition stage toward cultivable forms. I have received from Abyssinia, from Dr. Bald-

rati, director of the Office Agraire Experimental, two lots of Abyssinian oats; one, Dr. Baldrati writes me, is made up of an abundant spontaneous form, the other of the form cultivated not for grain, but for forage. The wild oat was hairy with very fragile articulations. The other was glabrous or pretty near it, and with articulations retaining the grain better.

In cultivation at the Botanical Station, I have found all the transition stages between *A. wiestii* and *A. abyssinica*, which is the cultivable form of it.

A. abyssinica has therefore been wrongly connected with *A. sativa*. It is a form still half-wild. It appears, also, to be produced by the transformation of a native Avena, developed and modified in cultivation.

Although the differences between *A. barbata* and *A. wiestii* may be of little importance, it seems that these two plants are unequally xerophilous in dry places, *A. barbata* being simply the oat of the arid places of the Tell (the coastal region of Algeria), while *A. wiestii* is purely a desert plant.

The domestication of *A. wiestii* is as yet no more than outlined; it will be necessary to perform a vigorous segregation of the forms in the mixture and by appropriate treatment, either quickly or gradually by using patience, to obtain cultivable races superior to the *A. abyssinica* in use by the Abyssinians.

ORIGIN OF AWNLESS OATS.

In this study of the materials within my reach I do not pretend to have elucidated completely the question of the origin of all our oats. The awnless oats are also connectable with primitive species. If all transitions between the wild and the improved forms (intermediate forms which one may regard as the stages of a gradual improvement by culture), are found in the series of cultivated oats, it appears admissible for the awnless oats, that sudden mutations might have intervened. These oats are characterized by teratological anomalies; they are monstrosities such as produced *Triticum polonicum*.

The large Chinese awnless oat has the closest analogy with *A. sterilis*. I have been able to hybridize it with *A. sterilis culta*.

The study of the domestication of Avena presents, from the genetic point of view, some rather substantial arguments in favor of an ambient medium, a modifying agent causing fluctuations which end in the formation of varieties well characterized and fixed by selection.

Avena fatua in cultivation loses the fragility of its articulations, its hairs, its awns. It becomes a domesticated plant, but all the stages of its changes are easily retraced. Cultivated in very diverse surroundings, *A. sativa* has today a very numerous and extremely varied lot of domesticated descendants, as should be the case if the environment causes fluctuations.

A. sterilis culta has not been submitted to the same tests. This variety, cultivated on the Mediterranean borders, has until recently never been carried to other climates. The influence of the cultural environment appears to be very rapid, since Buckmann according to Darwin (Variations of Animals and Plants under Domestication, p. 330, New York, 1897) in a few years of careful culture and selection, converted *A. fatua* into two cultivable races, almost identical with the races already cultivated.

In oats, the modifications of the wild types are in reality not deep. The suppression of the fragile articulations has been considered as having much too great importance in Avena, as in Triticum and Sorghum. The fragile rachis may become tenacious by the simple play of fluctuating characters. It is nevertheless worth while to remark that in the natural habitat, the fragility of the rachis is never lacking in the wild types. This transformation seems to take place only under the influence of cultivation.

Hybridization between the cultivated species of oats has not yet been methodically attempted to my knowledge, and there is here a very interesting open field. It is true that we have yet to determine in what degree a true hybridization will be possible. If *Avena fatua sativa* may be crossed with *A. sterilis*

culta, a progeny may be produced having very useful mixed characters. *A. abyssinica* will gain by being crossed with the really superior *A. strigosa*. But in the matter of hybridization there is much more to be gained from experimentation than from the mere discussion of theoretical views.

SUMMARY.

Until recently, *Avena fatua* has been regarded as the ancestor of the cultivated oats comprised under the term *Avena sativa*.

Study of the wild forms of *Avena sterilis* has led me to consider that the cultivated oats of the Mediterranean countries are descended from this wild species.

The Algerian oat, and the oats of Italy, possess morphological characters found in *Avena sterilis*.

Avena barbata has given rise to some cultivated forms, such as *Avena strigosa*.

These three wild types of Avena appear to have been modified by cultural influences. In various cultures of the cereals, of flax, etc., may be found mutational forms which nearly approach cultivated types. One series of forms is characterized by the reduction of the hairs on the glumes, in another series the awn is reduced, and a third series is distinguished by the solidity of the rachis, which becomes gradually less articulated. A variation of the nature of a monstrosity may also be observed, in which the glume is less compact, so that the caryopsis falls out before maturity. This mutation gives rise to "naked oats."

In conclusion, at least three wild species of Avena, under the influence of culture, may acquire characters fitting them for cultivation. These three species preserve the ancestral characters by which they are adapted to different climates.

Avena fatua gives rise to oats adapted to temperate and mountainous regions; *Avena sterilis*, to oats adapted to the southern countries, and to saline soils; *Avena barbata* to races adapted to dry countries.

PLANS FOR INTERNATIONAL CONGRESS

The American section of the international committee on arrangements for the second International Eugenics Congress met last month. Bleecker Van Wagenen and Frederick Adams Woods were the members present, while H. H. Laughlin, W. Bayard Cutting and C. B. Davenport met with them by invitation. An organizing committee for the next congress was selected, as follows: David Fairchild, Frederick Adams Woods, Raymond Pearl, E. L. Thorndyke, Vernon L. Kellogg, and C. B. Davenport, chairman. This committee met in New York city on January 2 and elected Henry Fairfield Osborne of New York as president of the congress, which will be held in that city in September, 1915.

The Promise of Mendelism

When it is remembered that in wheat, for example, resistance and nonresistance to the attacks of disease, earliness and lateness of ripening, good and bad milling quality, are all pairs of Mendelian allelomorphs, and that it is now possible to take a different example of each of these qualities from each of three different strains, and to combine them together in a single new variety with perfect certainty and in four generations, it does not require much imagination to foresee that every department of the animal and plant breeding industries must sooner or later benefit enormously from Mendel's discovery.—R. H. Lock: Recent Progress in the Study of Variation, Heredity and Evolution (1906).

MENDELISM IN GREAT BRITAIN

Careful Experiments Being Carried on in Many Ways to Determine Operation and Limitation of Laws of Heredity—First Researches Purely Experimental, but Intensely Practical Ones Now Being Made by Numerous British Men of Science

R. C. PUNNETT

The Arthur Balfour Professor of Genetics in the University of Cambridge, England.

THE dramatic discovery of Mendel's work on plant-hybridization in 1900 inaugurated a new era for the breeder of plants and animals, and the opportunities for advance in the knowledge of heredity were in no country more rapidly seized than in Great Britian. The seed here fell upon prepared soil, for the problems to which Mendel found a key had already begun to engage the attention of Mr. Bateson and of Miss Saunders in Cambridge. The account of the experiments which they had started in 1897 and published as the well-known first report of the Evolution Committee to the Royal Society in 1902 was the most important contribution to the subject since Mendel's own paper, and was the first to open men's eyes to the vast possibilities latent in Mendel's work. A group of workers rapidly gathered round Bateson in Cambridge, and the contributions to be found under the names of Doncaster, Gregory, Lock, Staples-Browne, Miss Durham, Miss Wheldale, and others bore witness to the activity of the rising school of genetics in the University.

All this work, like Mendel's own, was designed and carried out purely with the desire to gain definite knowledge of the workings of heredity, and little or no attention was paid to the economic results which might flow from the application of this knowledge to the affairs of those who bred animals and plants for profit. The material for study was selected on the ground of its cheapness, of the ease with which it could be worked, and of its suitability for giving a speedy answer to the problems put to it. Sweet-peas, mice, stocks, moths, snapdragons, and poultry—such was the material investigated, and except for the last-named it could hardly be said to possess much economic importance.

CEREAL IMPROVEMENT.

But it so happened that the stimulus to genetic work coincided with the rapid rise of the School of Agriculture in the University, and the enormous practical importance of the new knowledge was immediately appreciated by Professor Biffen, who was then starting his now-famous experiments in the crossing of cereals. By making use of the methods of Mendelian analysis he was able to show that such qualities as strength, yield, and immunity to rust were transmitted in accordance with Mendel's law of segregation, and consequently are under the control of the investigator, who can now devise suitable experiments for combining them together at will. Improved wheats of this kind have already come into use in England, and, judging by the competition there is to secure the seed, they have already proved themselves a great success. The analysis of the wheat-plant is still being actively carried on

[1] Reprinted from the Bulletin of Agricultural Intelligence and Plant Diseases of the International Institute of Agriculture, Rome.

in Cambridge by Professor Biffen and his co-workers, and there is no doubt that as time goes on even better and more profitable varieties will be at the service of the British farmer.

It is pleasant to be able to record that the importance of the work has been recognized by the Government, who have placed a considerable annual sum at the disposal of the School of Agriculture for research in plant-breeding. This has rendered possible an increase in the scope of the work, and experiments are now being carried out on other plants besides cereals. Among investigations now under way are some concerned with the transmission of fertility in fruit-trees, while the striking success of Biffen's work on the nature of immunity to rust in wheats has led to the search for naturally immune individuals in other forms of plant-life. Experiments with potatoes have been in progress for several years, and, thanks to the energy of Dr. Salaman, working on his own estate near Cambridge, and of Mr. Lesley, of the School of Agriculture, the formation of a decent potato, naturally immune to *Phytophthora infestans*, seems within measurable distance of realization.

WORK WITH POULTRY.

Nor are the researches at Cambridge confined to plants. Poultry was one of the first subjects of experiment by Bateson, and during the past ten years much has been learned of the transmission of various characters. Offering as they do a number of features showing sex-linked inheritance, poultry are of importance for gaining an insight into the nature of sex, and of studying the peculiar influence of each sex in the transmission of hereditary properties. Several of these sex-limited characters are now under investigation at Cambridge, while parallel experiments are being carried on by Professor Bateson at Merton.

Two other series of experiments likely to lead to knowledge of economic value are also being carried on at Cambridge. The first of these is concerned with the inheritance of size, and consists in carefully following out the result of a cross between an ordinary fowl and a bantam. The work is not yet sufficiently advanced to permit of complete analysis, but the nature of the F2 generation raised last year strongly suggests that size depends upon definite factors which exhibit ordinary Mendelian segregation. The other set of experiments mentioned concerns the inheritance of the brooding instinct in the hen and of the brown color of the egg-shell. In England brown eggs are of greater value than white, but hitherto no breed laying brown eggs and in which the hens never want to sit has yet been established. It may be that brown eggs are incompatible with the non-broody habit, just as it is sometimes stated that a breed of cattle cannot be at the same time first rate in both milk-production and beef. It is hoped that the experiments in progress will eventually give definite evidence upon this point.

Experiments have also been undertaken with sheep where the results of a cross between merino rams (from Australia) and Shropshire ewes are being carefully followed. The experiments have just reached the F2 generation, and it is hoped that the knowledge gained from them will eventually render it possible to combine the fleece of the merino with the good mutton qualities of other breeds.

SWEET-PEA EXPERIMENTS.

Besides the work just mentioned, there are other sets of experiments being carried out at Cambridge and Merton which may be regarded as forming a group by themselves. Bateson in 1905 was the first to describe in sweet-peas a remarkable case in which two characters each exhibiting ordinary Mendelian segregation nevertheless showed a peculiar distribution with regard to one another. In this particular instance the characters dealt with were color, blue being dominant to red, and pollen-shape, long being dominant to round. Blue long x red round gave blue long in F1, and in F2 the expected ratio 3 blue: 1 red and also 3 long: 1 round. But the proportion of rounds among the blues was only about 1 in 12, whereas among the reds the rounds were in

excess of the longs to the extent of about 3 : 1. Since that date many other cases of this peculiar association of characters have been discovered in other plants as well as in sweet-peas, and certain generalizations have emerged from the study of them. We now know that if *A* and *B* represent two factors respectively alternate to their absence (*a* and *b*), then if the original cross is of the nature *AB* x *ab* the characters *A* and *B* will be more or less completely associated in the F2 generation, so that of the four possible classes *AB* : *Ab* : *aB* : *ab* the first and the last will be the most numerous. If, however, the original cross is of the form *Ab* x *aB*, then of the four classes in F2 the *AB* one will be about twice as numerous as either of the two classes *Ab* and *aB*, while the class *ab* will be very rare. Where *A* and *B* go into the cross in association they tend to remain associated in F2, whereas when they go into the cross dissociated they tend to remain dissociated in F2. This peculiar phenomenon is not as yet properly understood, and it is with a view to obtaining further knowledge that experiments are being carried on at Merton by Professor Bateson, and at Cambridge by Miss Saunders with stocks, by R. P. Gregory with primulas, and by the writer with sweet-peas.

Recent work, more especially that of Morgan in America, has shown that similar phenomena occur in animals, and there is no doubt that a proper understanding of them will eventually turn out to be of much importance for the breeder of plants and animals. It is a matter of common observation that characters seem at times to be transmitted in bunches, as it were, from one parent or other to the offspring, and it is likely that in such cases we are dealing with phenomena of the kind just outlined.

BATESON'S INSTITUTION.

The best-equipped institute in Great Britian for the study of genetics is undoubtedly the John Innes Horticultural Institution at Merton, near London. Started in 1909 with funds derived from private bequest, it was fortunate in securing Professor Bateson, who left Cambridge in 1910, as its first Director. Fortunately, also, its scope is broad, and the experimental work undertaken is concerned with the unravelling of the principles of inheritance in the widest sense, apart from considerations of direct economic return. Numbers of experiments are at present being carried out by Professor Bateson and his staff, principally with plants, not the least interesting being a series of experiments dealing with fertility and sterility in fruit-trees.

Besides Cambridge and Merton there are several other places where genetic research is being carried on. Mr. Hurst, one of the pioneers in Mendelian studies, has established an experimental station at Burbage, near Leicester, which aims at the production of economically valuable varieties of plants and animals by working upon Mendelian lines. Mr. Hurst is experimenting with many different plants and animals, and some of his most interesting experiments concern horses, and aim at the production of a pure race of steeplechasers—*i.e.*, of animals with a special aptitude for hunting.

Genetic research is also being carried on by Professor Keeble at University College, Reading, the chief material investigated being primulas. But perhaps the most interesting work from this source is that dealing with the chemical side of genetic problems. It is well known that in primulas there are white flowers of two kinds—viz., those dominant and those recessive to colored. Professor Keeble and Dr. Armstrong have recently amplified the work of Miss Wheldale and others, and have demonstrated that these two forms of white, though alike in appearance, can be distinguished by definite chemical tests. Such work opens up a new and important field of study, and it is possible that as this branch of knowledge develops the genetic analysis of plants and animals will be greatly simplified by the substitution of direct chemical tests for the elaborate series of breeding-experiments which are at present necessary.

Among the experimental work in progress in England should be mentioned that of Mr. Staples-Browne, of Bampton, near Oxford, who is continuing his researches with pigeons, more especially with reference to sex-limited characters; also the work of Trow, of Cardiff, who has recently contributed a valuable paper on inheritance in *Senecio*. In this paper and in another shortly to appear Dr. Trow has made a definite advance in the understanding of those peculiar cases of association between characters to which reference has already been made.

In Ireland, Professor Wilson, of Dublin, has lately brought together a number of records dealing with the heredity of coat-color in cattle and horses and with the milking-capacity of cows.

Scotland has also made a start by creating a Lectureship of Genetics in the University of Edinburgh, to which Mr. Darbishire was recently appointed.

In conclusion, it should be mentioned that the study of genetics in Great Britian is not confined to those who work on these islands. Cambridge sends her students all over the world, and the value of genetic research to the breeder is evidenced by the work of Balls on cotton in Egypt, and by that of Leake and of Howard on cereals, cottons, and other plants in India.

General Principles Not Enough

So far as practical results are concerned, it is not enough for men of science to nvestigate the facts and the principles of heredity, and to attempt to lay down the principles of eugenics, as the science which deals with the improvement of the race is now called. It is not alone enough for moralists to preach. The hope of the future lies in the slow development of those habits, those social instincts arising inevitably out of the actual facts of life and deeper than science, deeper than morals. The new sense of responsibility—of responsibility not only for the human lives that now are, but the new human lives that are to come—is a social instinct of this fundamental nature. Therein lies its vitality and its promise.—Havelock Ellis: The Problem of Race Regeneration (1911).

Scientific Knowledge Required

The question of improving the human race in this country has lately excited a good deal of attention. But without a scientific knowledge of the factors on which improvement and degeneration depend the discussion is not likely to be of much profit, and in such a case misdirected energy may be even worse than apathy. Without venturing to make any very positive suggestions, it may be at least pointed out that our present practice in these matters is in almost every case the very worst possible.—R. H. Lock: Recent Progress in the Study of Heredity, Variation and Evolution (1906).

Careful Selection Necessary

The principles of heredity teach us that education and training, however beneficial they may be to individuals, have no material effect on the stock itself. If they have any effect at all, this is undoubtedly unimportant in comparison with the effect which would be produced by the selection of individuals which exhibit desirable qualities. The demand for a higher birth-rate ought to apply strictly to desirables. Instead of this the cry is for education and physical training, processes which can have no permanent beneficial effect on the race.—R. H. Lock: Recent Progress in the Study of Heredity, Variation and Evolution (1906).

NEW PUBLICATIONS

THE INFLUENCE OF MONARCHS by Frederick Adams Woods, M. D. The Macmillan Company, 422 pp. $2.00.

This is an attempt to gauge the influence of the hereditary qualities of a man upon the history of his time; the man selected is the reigning sovereign.

The method of the study is to render a judgment, as objective and free from bias as possible, concerning the position of the reigning monarch in one of the three classes, plus, intermediate and minus. In the plus class one places the monarchs of exceptional talents for leadership, in the minus class are placed monarchs of feeble intellect and feeble moral control, in the intermediate class are placed those of intermediate qualities. In the same way, the change in the political condition and general prosperity of a country may be classified as plus, if very progressive, intermediate, if stationary, and minus if retrogressive. An agreement in the sign of the personality of the monarch and the prosperity of the country counts one for the hypothesis of influence of the monarch; a disagreement in sign counts against the hypothesis. The correlation in signs can be calculated and affords a measure of the influence of the monarch.

This method is applied in successive reigns in the medieval history of France, Spain, Portugal and the other leading nations of Europe. For example, the reign of the brave, wise, virtuous Gustavus Vasa led to the independence of Sweden and a vast development of her resources. In the following reign of the unwise, suspicious, headstrong Eric XIV treasure was wasted, national distress entailed and rebellion incited. Here the weak ruler permitted to decay what his strong predecessor has built up.

Altogether Dr. Woods finds 105 instances of a superior ruler associated with advancing conditions of his country as against only 11 cases where there is a decline. There are 87 cases where a national decline was associated with a weak ruler and 30 cases where there was progress with such a ruler but, in such cases, there was frequently a strong power behind the throne. If 0 measures no correlation and 1 perfect correlation, then the actual correlation found is measured by .6 or three fifths of a unit.

It still remains to consider the significance of this correlation. Did the conditions of national development determine the eminence of the king or *vice versa*? Evidence for the conclusion that the qualities of the king determine the fate of his country is found in three facts. First, the transition from + to — states of prosperity in the country is usually abrupt, closely following the accession of the king. Second, interregnums are almost always periods of national decline unless some strong member of the royal family is in control. Third, if conditions determined the rank of the monarch there should be less evidence of an inheritance of the intellectual qualities of a monarch than of some other characters not capable of being influenced by conditions, such as eye color; but the inheritance of intellectual qualities is not less than that of others.

The main conclusion that Dr. Woods draws from this study is "that the royal breed, considered as a unit, is superior to any other one family, be it that of noble or commoner." Proof that the superior quality of royalty is due to innate qualities is found in the facts that younger brothers are just as eminent in intellect as are those who succeeded to the crown; that many scions of royal houses have been exceedingly precocious; that, on the whole, their genius has been for war and government (for which the blood was selected in the first instance); and that 1 in 40 of royalty show intellectual preeminence of a grade not found in 1 in 4,000,000 outside of royalty. Royalty in Europe between the eleventh and eighteenth centuries is a demonstration of the overwhelming importance to a country of its "best blood."

C. B. Davenport.

Breeding Wild Game

What he considers the largest plant in the world for breeding and shipping live game is described by Paul Larsen in the December number of the Game Breeder. This is the estate of F. Horacek at Martinitz, Bohemia.

"The first day," says Mr. Larsen, "I visited the park for haired animals located in some high wooded hills. There are about twenty-five acres divided into five inclosures. Three of these usually contain six thousand hares and altogether twenty thousand are trapped in a season and brought to the inclosures. Mr. Horacek owns for trapping the hares, nets which are about nine thousand yards long, representing a value of over $8,000. During the season three thousand netters are employed to trap game. The other two inclosures are filled with deer and boars.

"The second day of my visit I enjoyed seeing the pheasantries and partridge aviaries. The first named consist of fifty-four covered and three open pens which will hold at one time about ten thousand pheasants. The second named consist of two hundred and ninety-eight pens, and over sixty thousand partridges pass through these inclosures during a season.

"While abroad I thoroughly studied the methods of distinguishing the sexes of partridges," the writer continues. "Most people believe that the reddish-brown crescent on the breast of the bird is a distinguishing mark of the male, but this certainly is not so. I observed that a large proportion of the hens have this mark and even larger and more well defined. One day while handling about two hundred birds, in order to investigate this subject, I ascertained that the best way of determining the sexes is that the males have a red spot just back of the eye which is especially prominent at the mating season. The general color of the male, also, is brownish while that of the female is grayish. The feathers of the first mentioned are marked lengthwise and crossed with brown stripes while the feathers of the female are barred with ashy-gray and sometimes with black stripes. The head of the male shows no pearl-like markings which can be observed on the head of the female."

On Marriage Certificates

Editorially reviewing recent American legislation on the subject of health certificates as a requirement for marriage, the Medical Record (New York, December 6, 1913) remarks:

"In many of these the provisions of the law have far outrun the results of scientific investigation. It is in fact still an open question whether confirmed criminals and feeble-minded persons are especially apt to propagate their own kind unless they mate with persons who, like themselves, carry a neuropathic strain. With few exceptions the impediments to marriage, imposed by the new legislation, appear to disregard the unsettled state of eugenic science, and assume that the theories advanced by this or that particular school have correctly solved the principles underlying the inheritance of good or bad germ-plasm."

Hereditary Chorea

Hereditary chorea, usually known as Huntington's chorea, is described in the Boston Medical and Surgical Journal for Nov. 6, 1913, by Dr. William A. Boyd of the Westport, Conn., Sanitarium. He reviews the history, from the discovery in 1842, of this disease, which is one of the most clearly marked and indisputable of the disease-factors of cacogenics, and manifests itself, in general, only in adult life. The disease has in recent years been studied by a number of genetists, all of whom have borne witness to its highly transmissible character; Dr. Boyd adds a case from his own experience, and gives an extended bibliography of the subject.

Register of Hybrid Orchids

An undertaking which should prove of real value to genetists is the foundation by the Royal Horticultural Society of London of an orchid register, to keep an accurate record of crosses made, thus continuing the compilation of data started by Rolfe and Hurst's Orchid Stud Book, published by the Orchid Review of London.

The new register will be international in character, and compiled in harmony with the Vienna and Brussels Rules of Nomenclature. It is announced in the following letter from the office of the Royal Horticultural Society in Vincent Square, Westminister, London:

"*November 28th, 1913.*

"The President and Council, acting on the recommendation of a Sub-Committee of the Orchid Committee, have decided to establish a Register of Hybrid Orchids at Vincent Square. Mr. R. A. Rolfe, of Kew, has been appointed Recorder. The Register will include all known Orchids.

"The President and Council accordingly invite Orchid raisers and growers amateur and professional, to bring their Hybrids, *when in flower for the first time* (even though they may not then be sufficiently developed to enter for award), and to enter the name and parentage of the plant, together with the exhibitor's name and address, on a Registration Form, which can be obtained from the R.H.S. Office, Vincent Square, S.W. This Registration Form should be sent with the plant, and it will be placed before the Orchid Committee, who, after satisfying themselves that the name is in order, will enter it on the Register. Once so recorded the name must be recognized for all crosses of similar parentage when subsequently shown, unless valid reason can be otherwise produced.

"W. WILKS, Secretary."

Color Inheritance in Pigs

Reviewing the observations made in Germany and the United States on the inheritance of color coat in pigs, Gustav Fröhllich describes the general conclusions in the Berlin Journal f. Landwirthschaft, LXI, 3, according to the Bulletin of the International Institute of Agriculture, Rome:

It appears that in the first filial generation of crosses the following are dominant:

I. *White* of Improved German Swine (Edelschwein) over:
   white and black of Hanoverians
   black of Berkshires
   greyish-black of European wild pigs
   greyish-black of Cornwalls
   red of Tamworths.
   black of Caucasian wild pigs.

II. *Greyish-black* of European wild pigs over:
   red of Tamworth.

III. *Black and white* of Hampshires over:
   red of Tamworth.

Importance of Genetics

I venture to express the conviction, that if the facts now before us are carefully studied, it will become evident that the experimental study of heredity, pursued on the lines Mendel has made possible, is second to no branch of science in the certainty and magnitude of the results it offers. This study has one advantage which no other line of scientific inquiry possesses, in that the special training necessary for such work is easily learnt in the practice of it, and can be learnt in no other way. All that is needed is the faithful resolve to scamp nothing.—William Bateson: Mendel's Principles of Heredity (1902).